FIG. 1

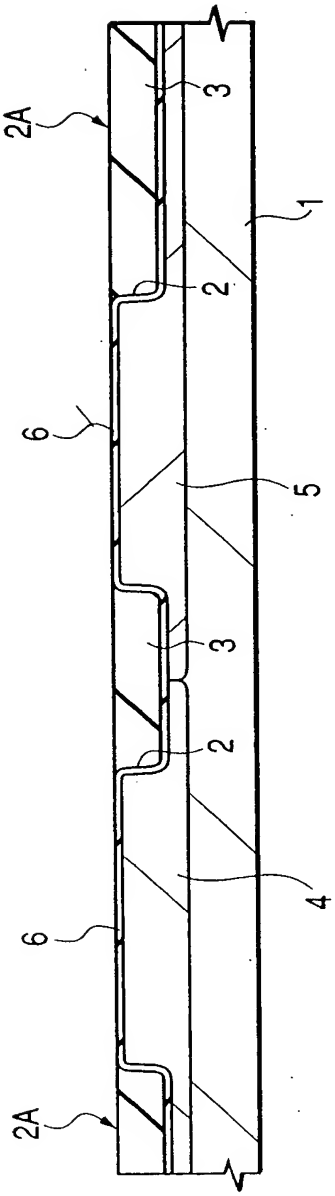


FIG. 2

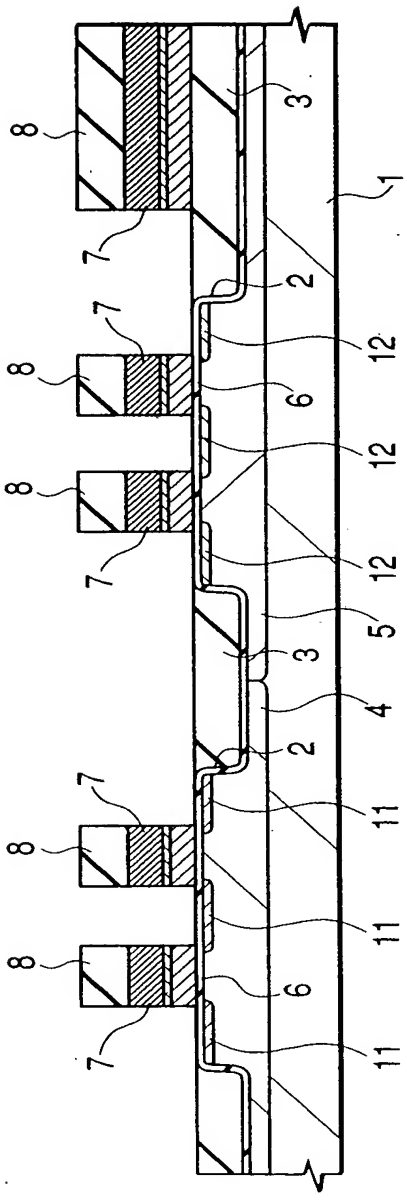


FIG. 3

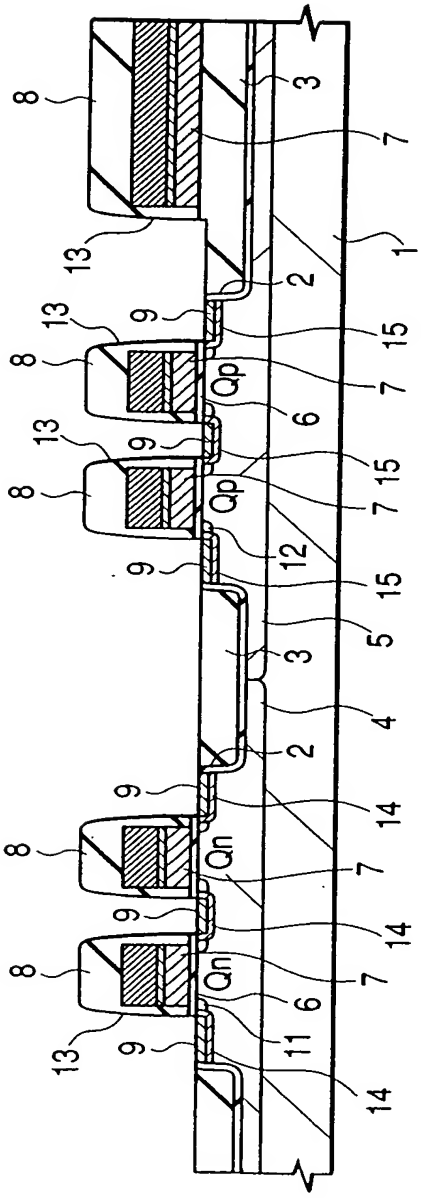

8
3
7
13
1
2
9
15
Qp
6
12
5
4
14
Qn
11

FIG. 4

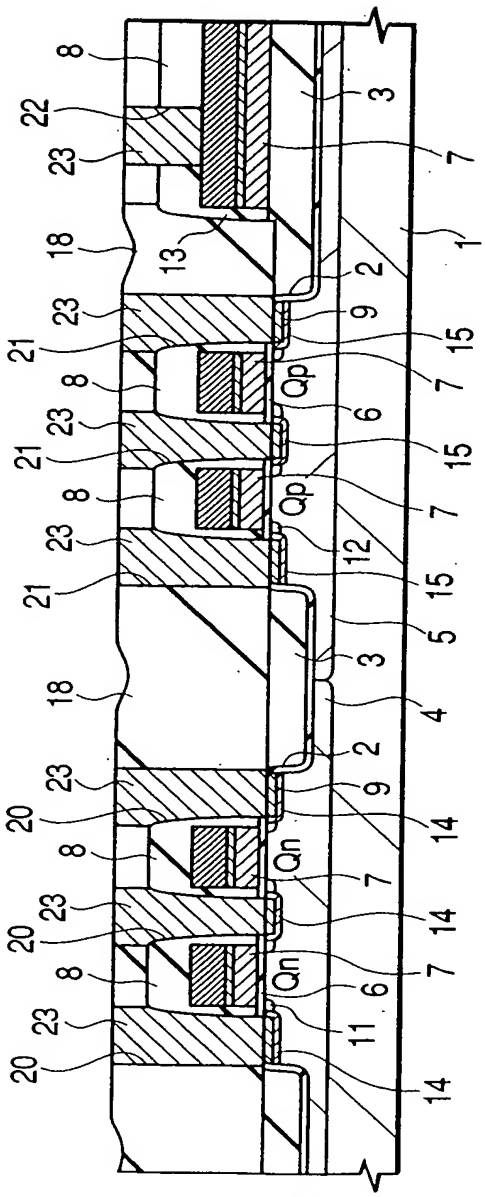
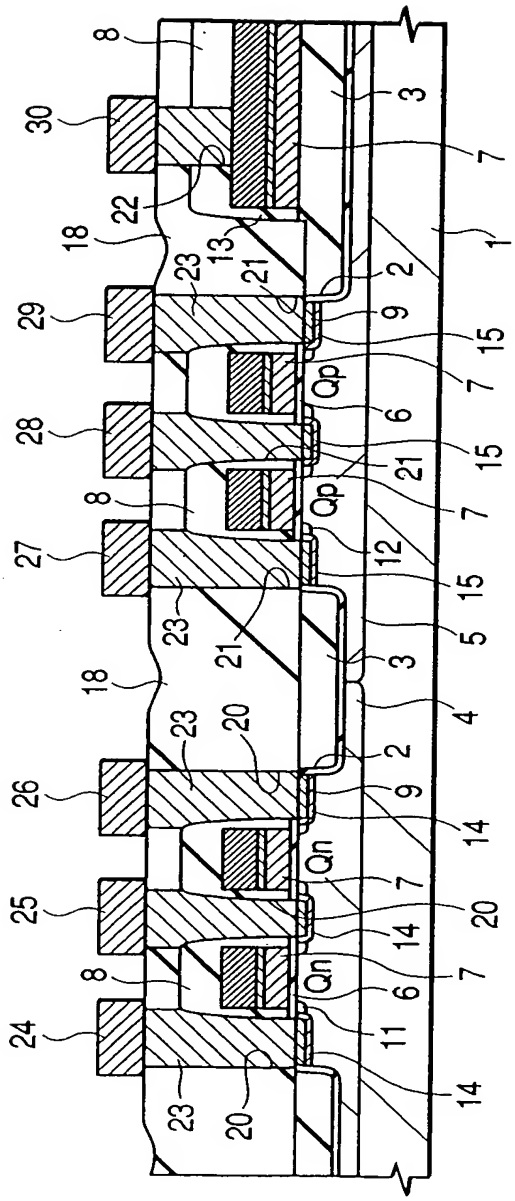

8
22
3
23
7
13
1
18
2
9
15
21
Qp
6
12
5
4
20
14
Qn
11

FIG. 5


8
30
3
7
22
18
13
1
23
21
2
29
9
15
Qp
7
6
28
21
15
Qp
8
7
27
12
15
23
21
5
3
18
4
23
20
2
26
9
14
Qn
7
25
20
14
8
Qn
7
6
24
11
23
20
14

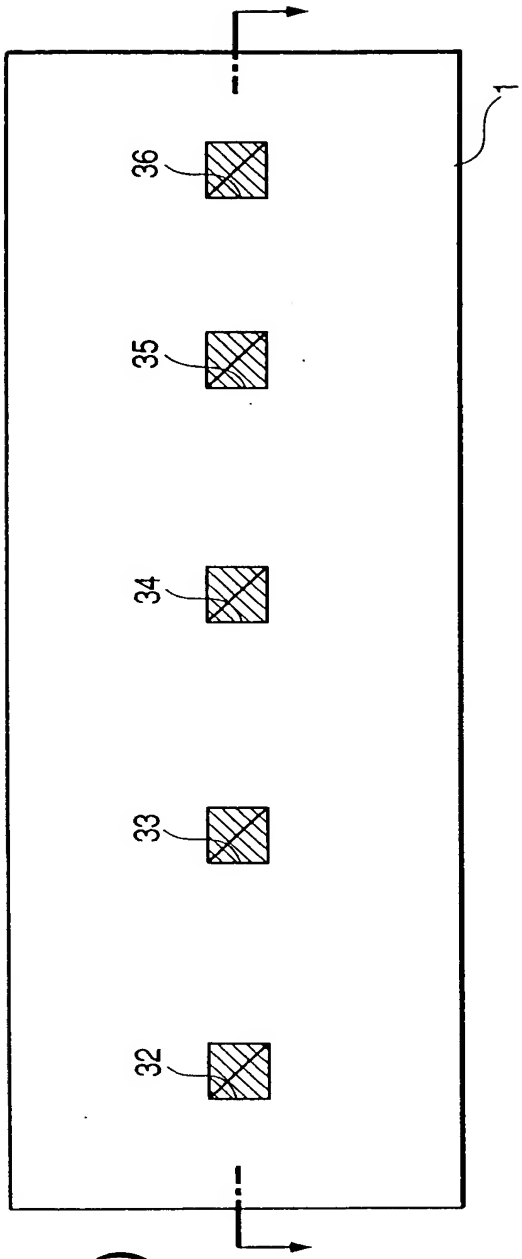


FIG. 6(a)

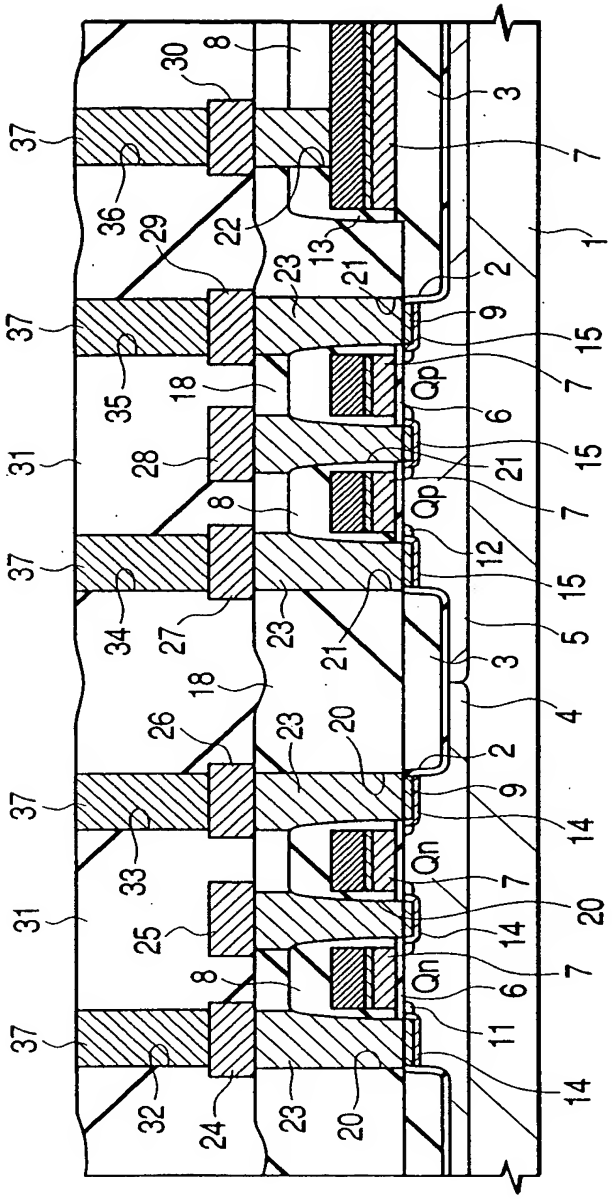


FIG. 6(b)

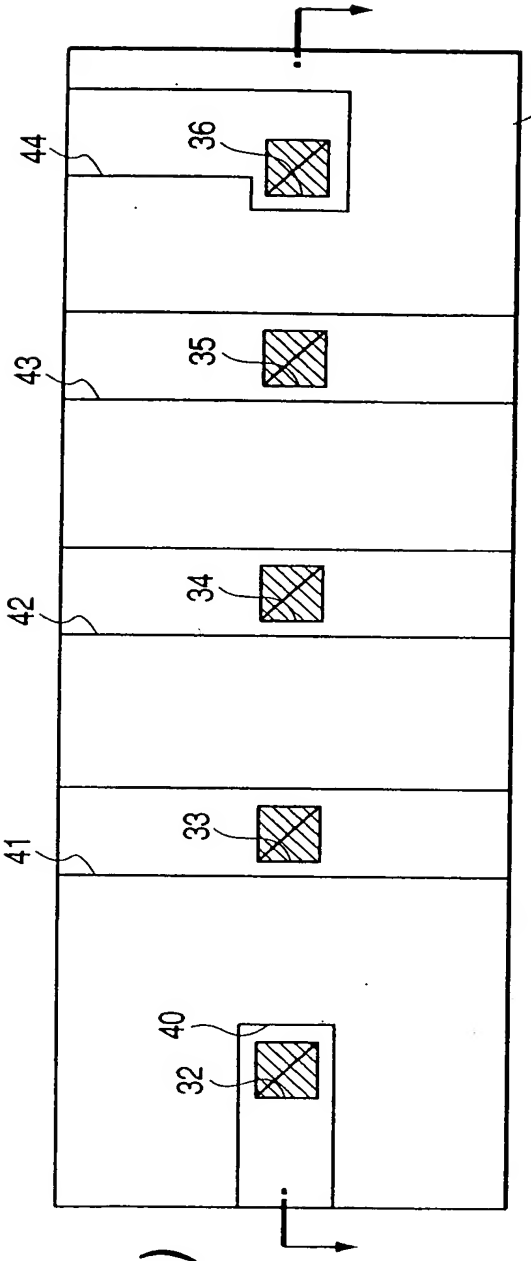


FIG. 7(a)

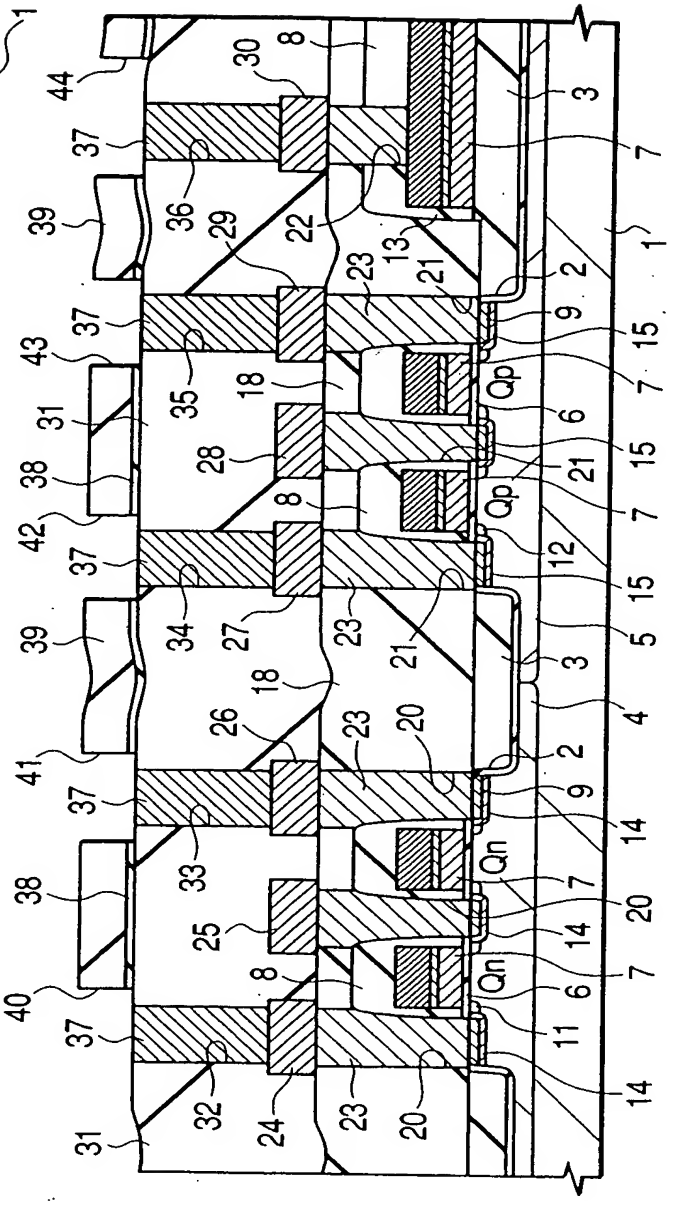


FIG. 7(b)

FIG. 8

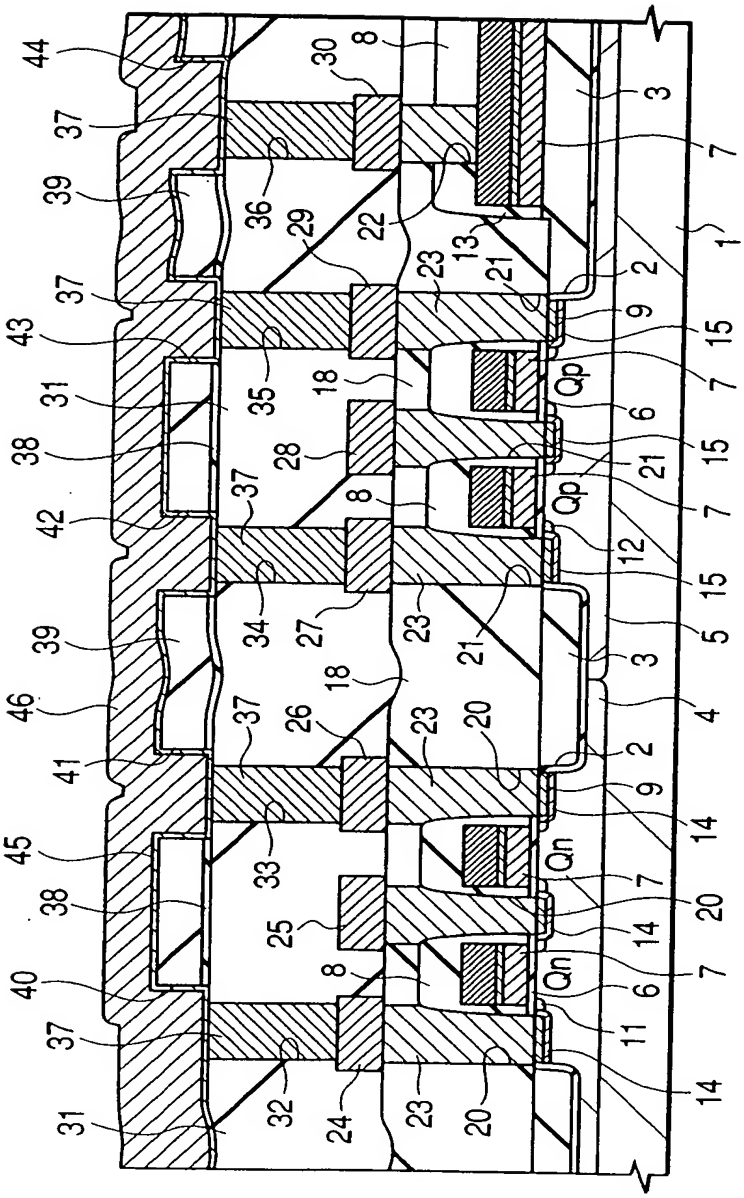


FIG. 9

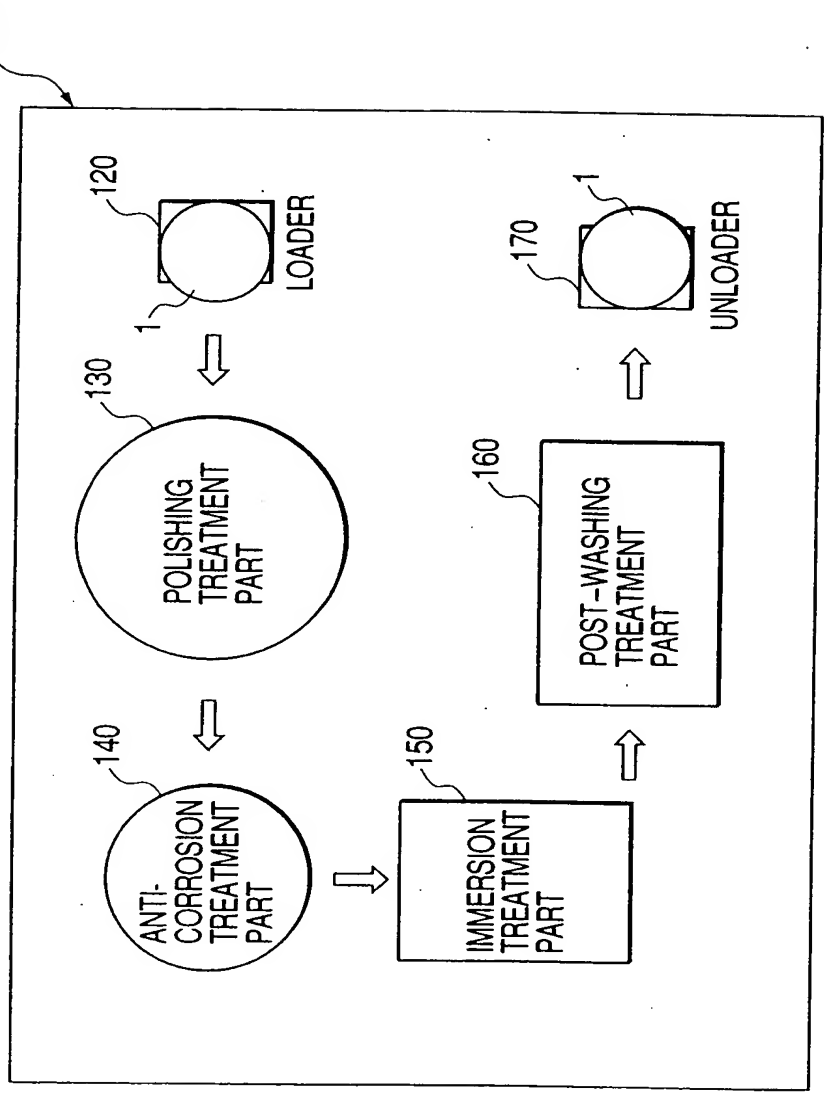

100
120
LOADER
1
130
POLISHING TREATMENT PART
140
ANTI-CORROSION TREATMENT PART
150
IMMERSION TREATMENT PART
160
POST-WASHING TREATMENT PART
170
1
UNLOADER

FIG. 10

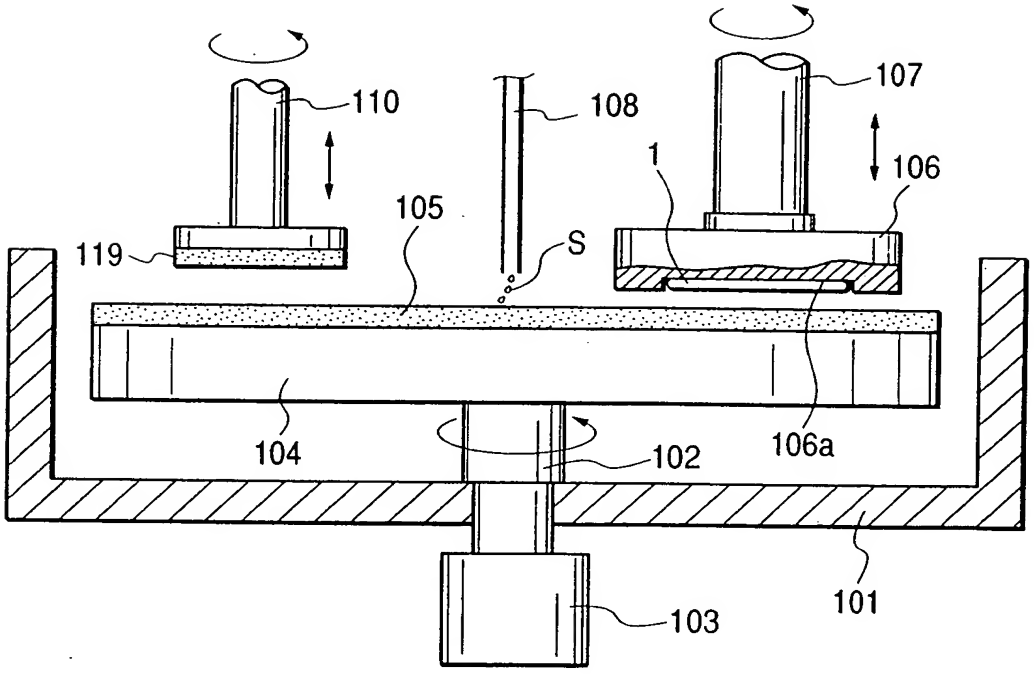


FIG. 11

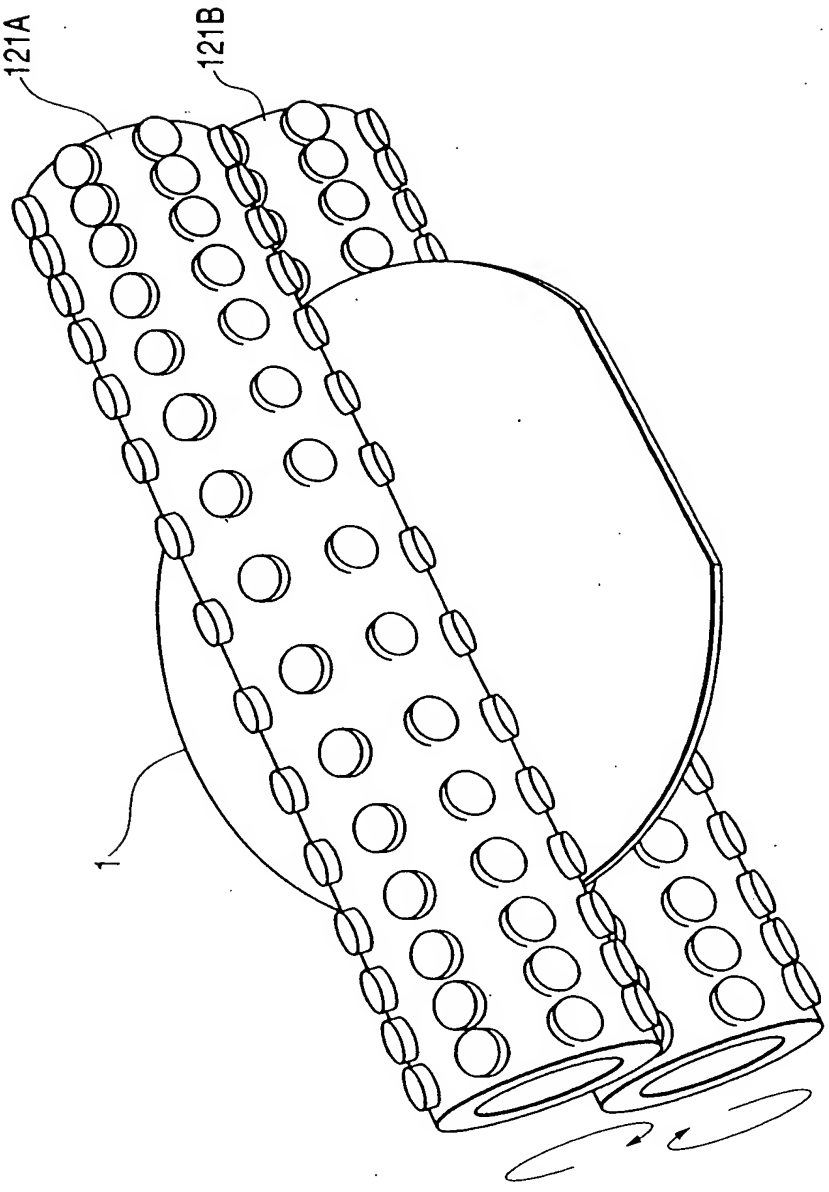


FIG. 12

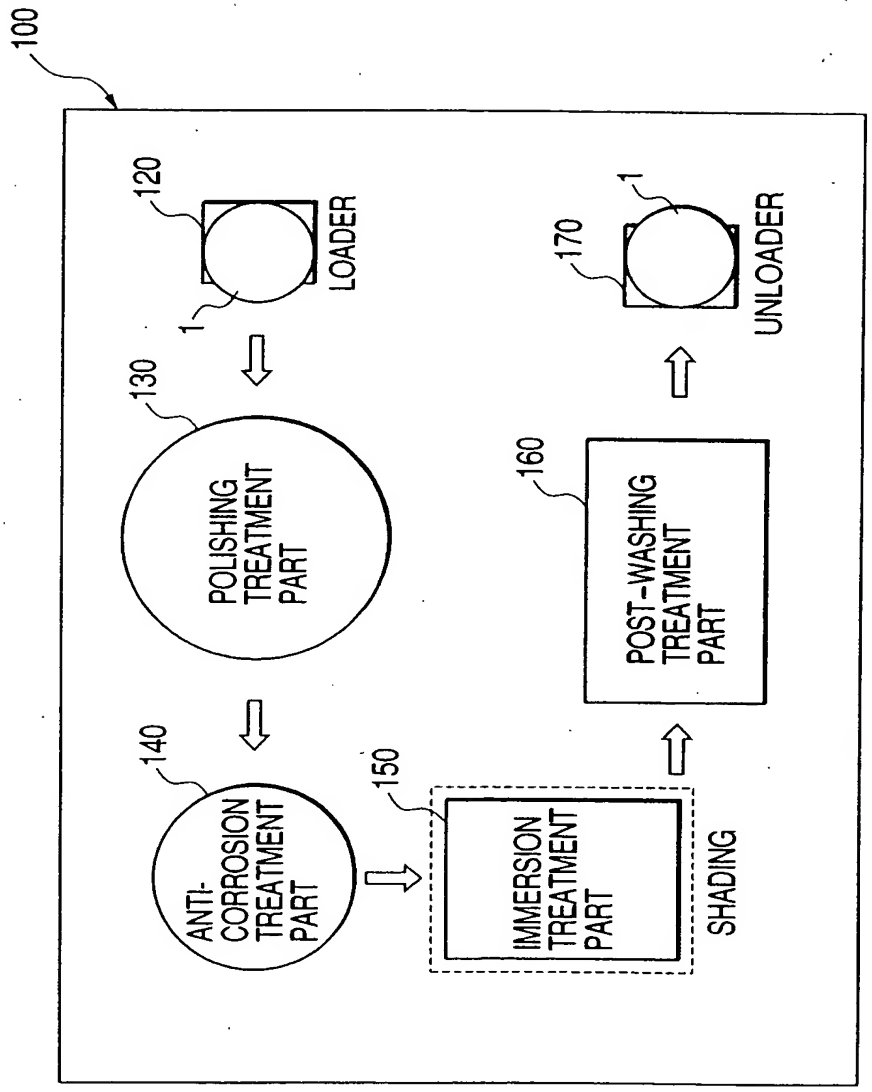

100
120
LOADER
1
130
POLISHING TREATMENT PART
140
ANTI-CORROSION TREATMENT PART
150
IMMERSION TREATMENT PART
SHADING
160
POST-WASHING TREATMENT PART
170
1
UNLOADER

FIG. 13

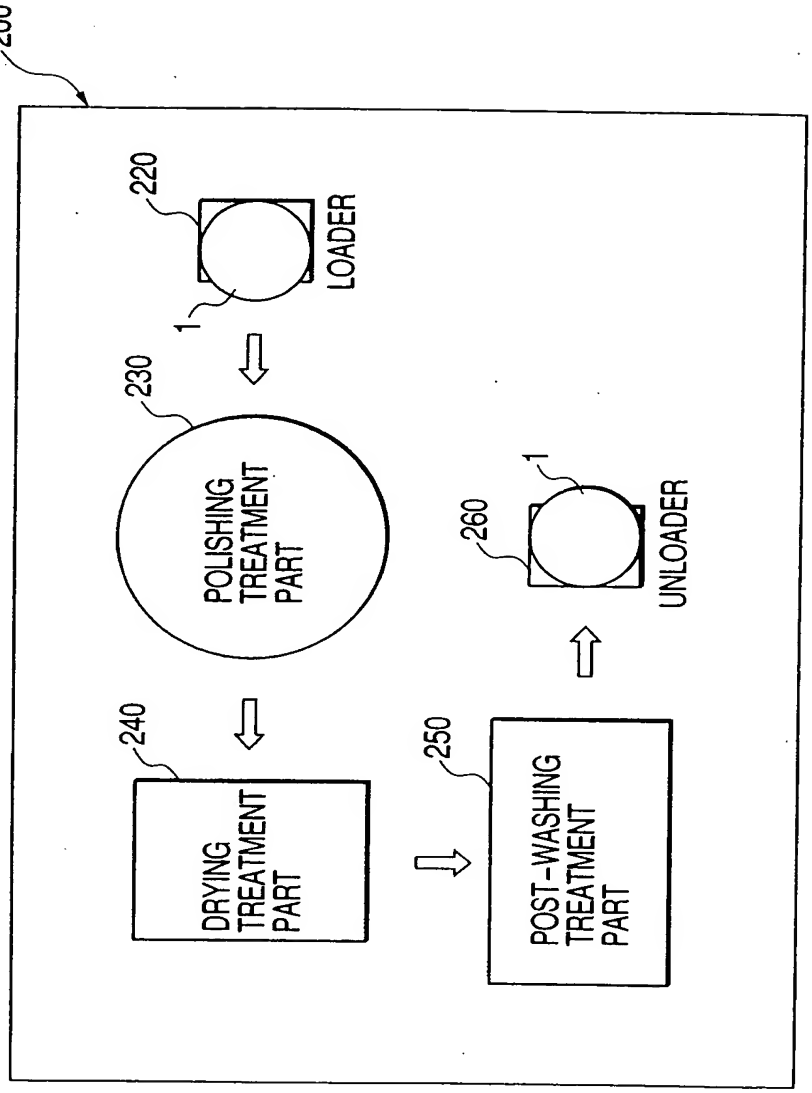

200
220
LOADER
1
230
POLISHING TREATMENT PART
260
1
UNLOADER
240
DRYING TREATMENT PART
250
POST-WASHING TREATMENT PART

FIG. 14

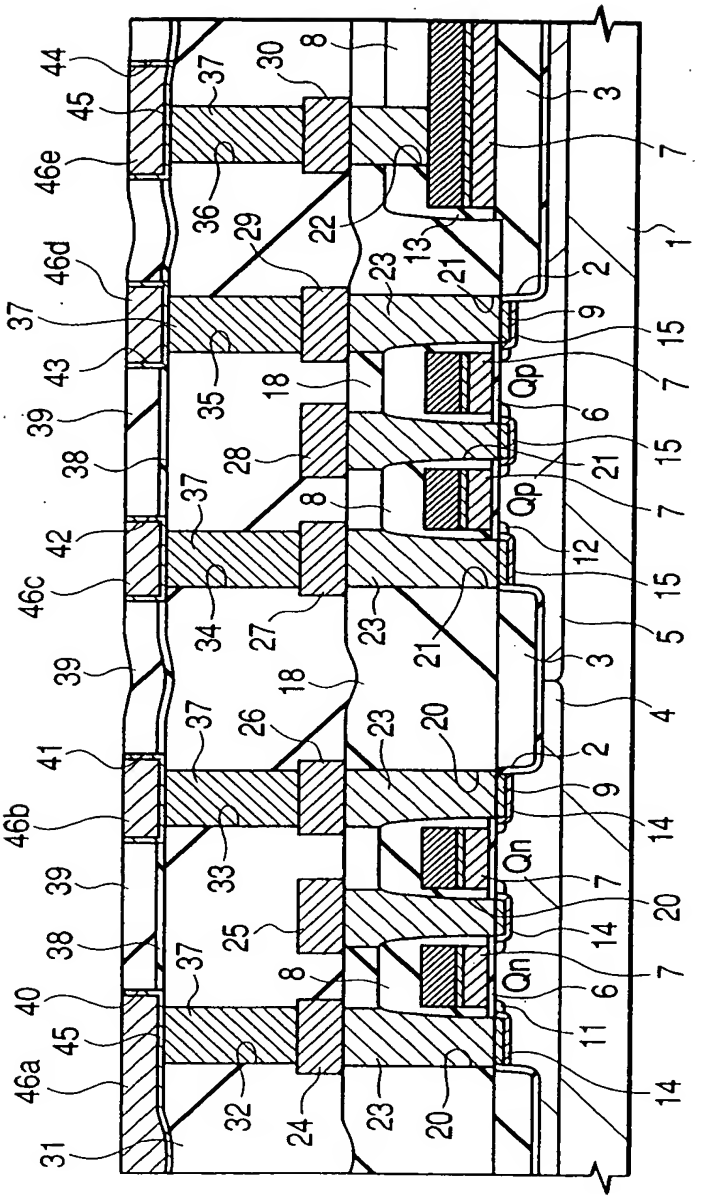


FIG. 15(b)

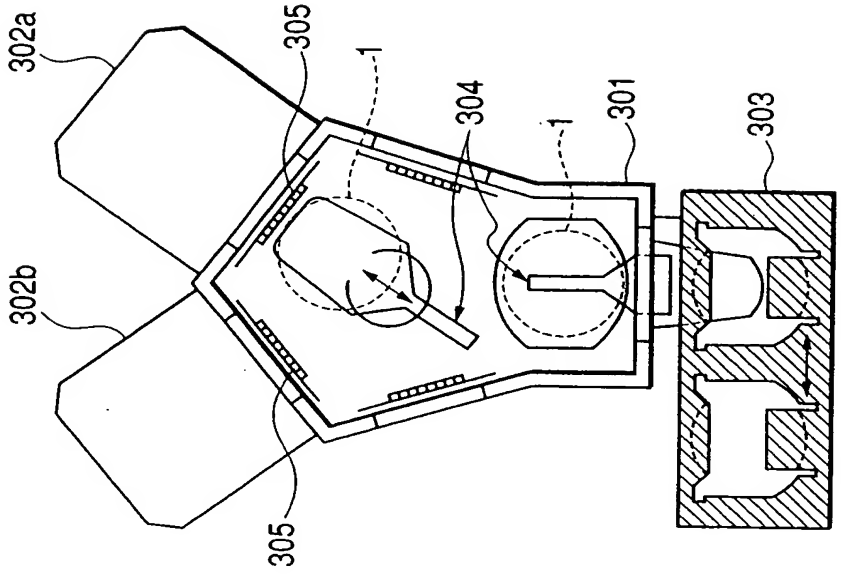


FIG. 15(a)

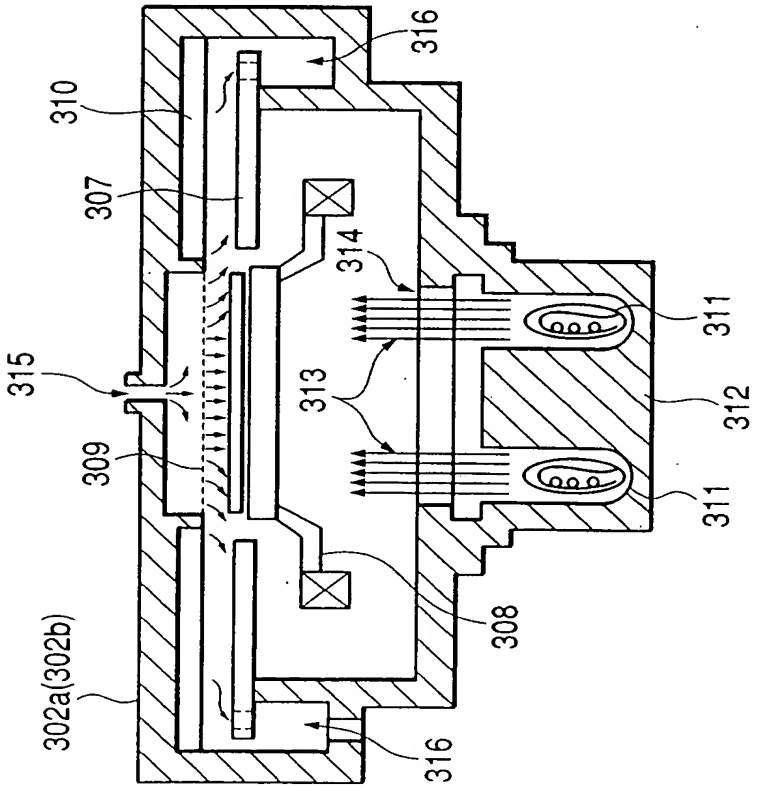


FIG. 16

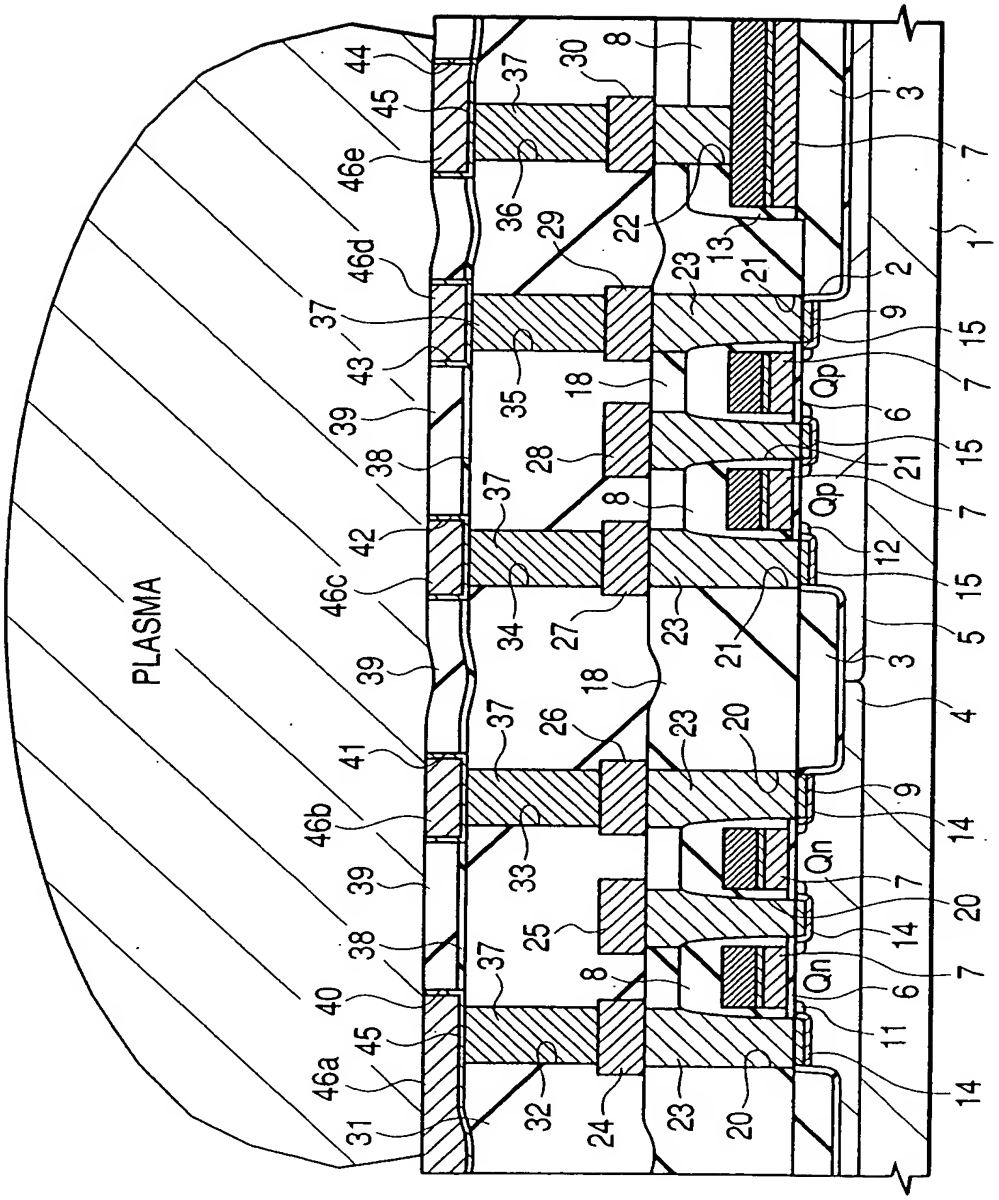


FIG. 17

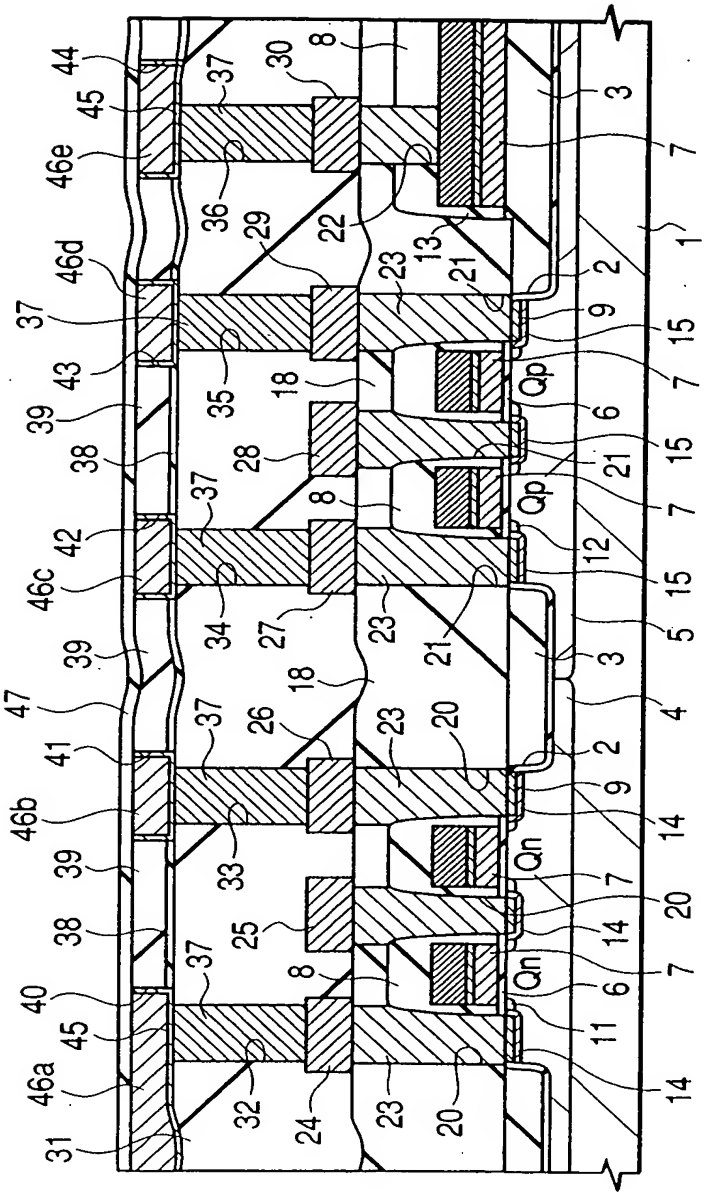


FIG. 18

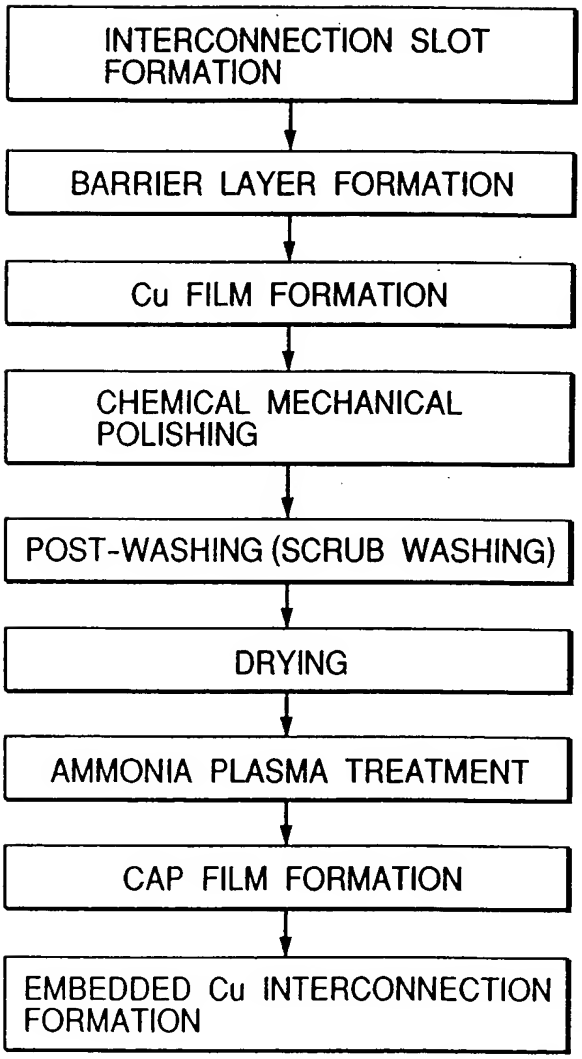

INTERCONNECTION SLOT FORMATION
BARRIER LAYER FORMATION
Cu FILM FORMATION
CHEMICAL MECHANICAL POLISHING
POST-WASHING (SCRUB WASHING)
DRYING
AMMONIA PLASMA TREATMENT
CAP FILM FORMATION
EMBEDDED Cu INTERCONNECTION FORMATION

FIG. 19

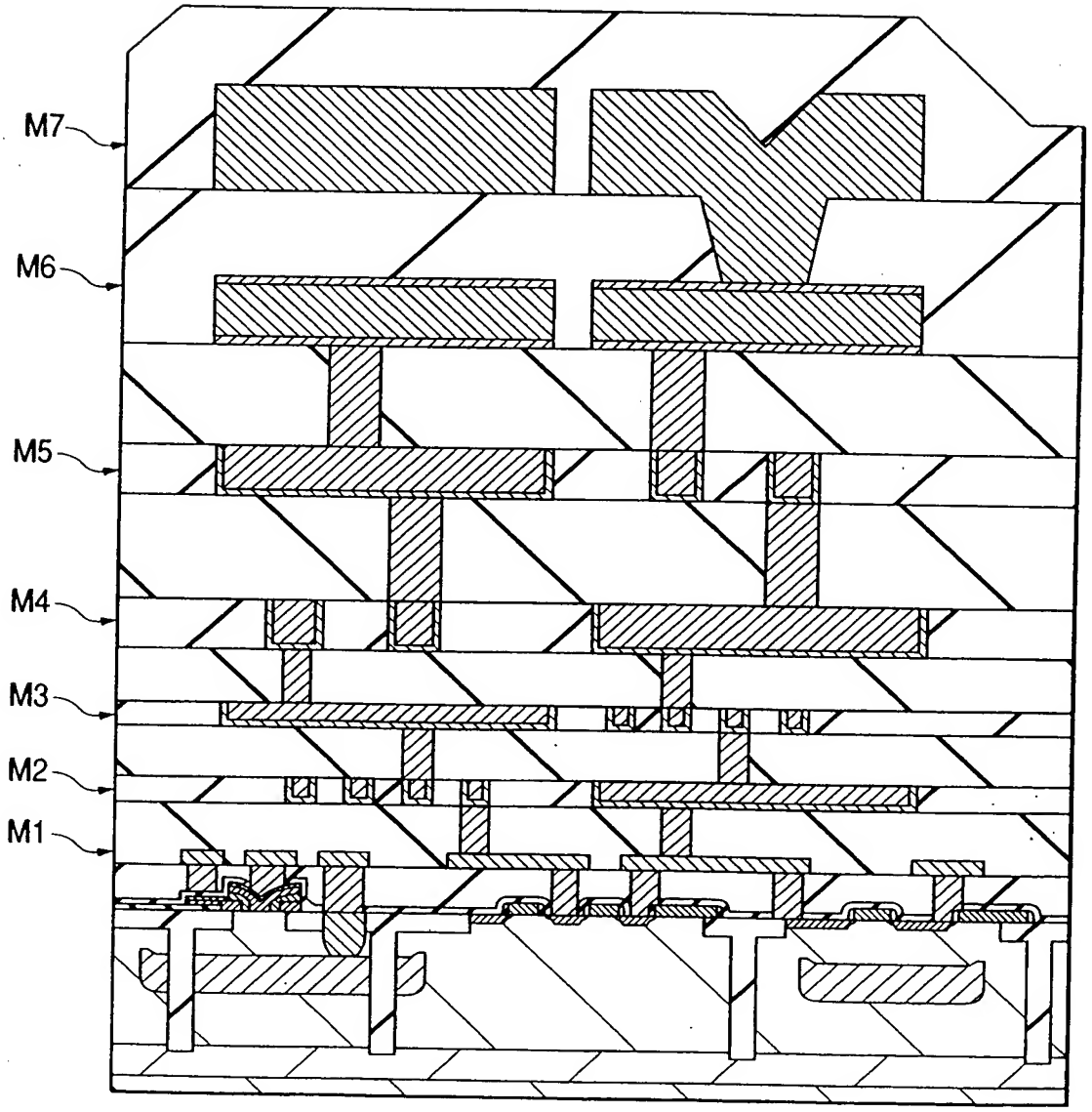


FIG. 20

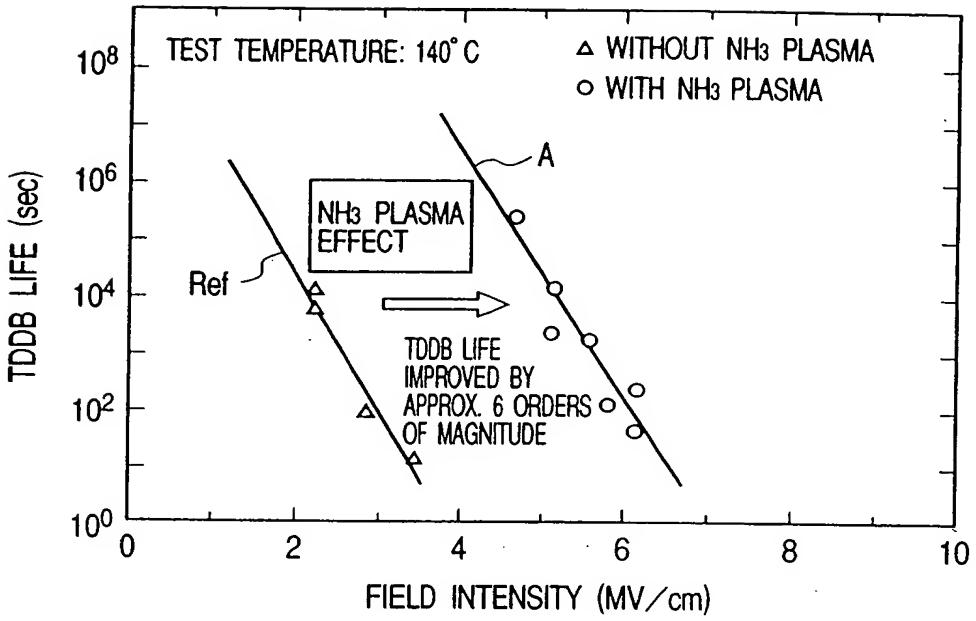

TEST TEMPERATURE: 140°C
△ WITHOUT NH3 PLASMA
○ WITH NH3 PLASMA
A
NH3 PLASMA EFFECT
Ref
TDDB LIFE IMPROVED BY APPROX. 6 ORDERS OF MAGNITUDE
TDDB LIFE (sec)
FIELD INTENSITY (MV/cm)

FIG. 21

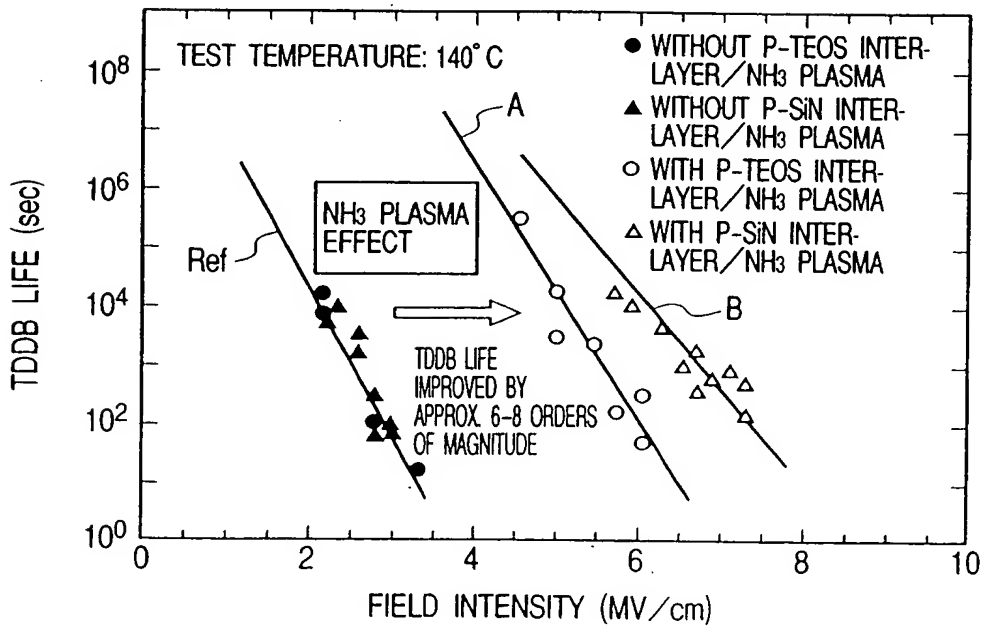

TEST TEMPERATURE: 140°C
● WITHOUT P-TEOS INTER-LAYER/NH3 PLASMA
▲ WITHOUT P-SiN INTER-LAYER/NH3 PLASMA
○ WITH P-TEOS INTER-LAYER/NH3 PLASMA
△ WITH P-SiN INTER-LAYER/NH3 PLASMA
A
B
NH3 PLASMA EFFECT
Ref
TDDB LIFE IMPROVED BY APPROX. 6-8 ORDERS OF MAGNITUDE
TDDB LIFE (sec)
FIELD INTENSITY (MV/cm)

FIG. 22(a)

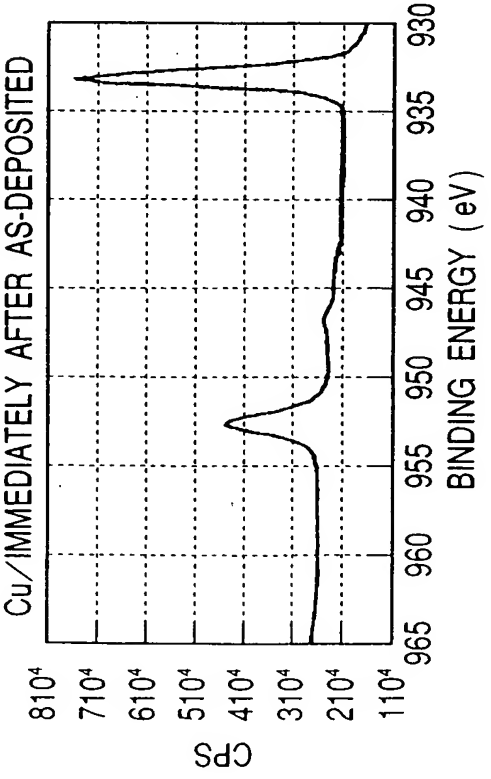


FIG. 22(b)

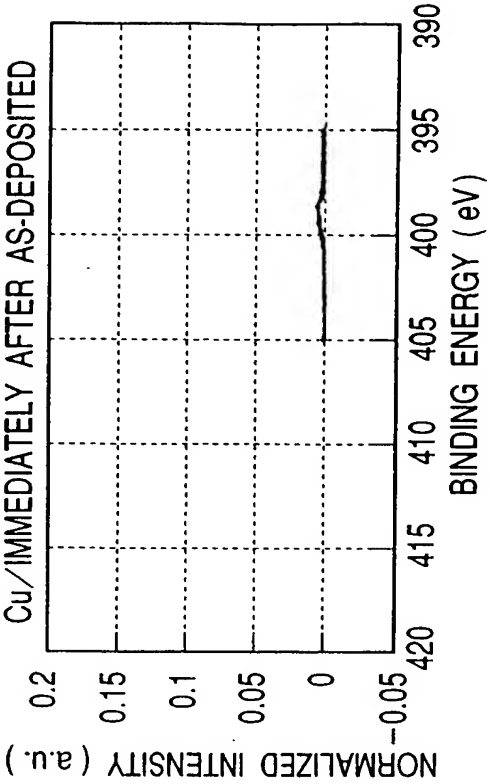


FIG. 22(c)

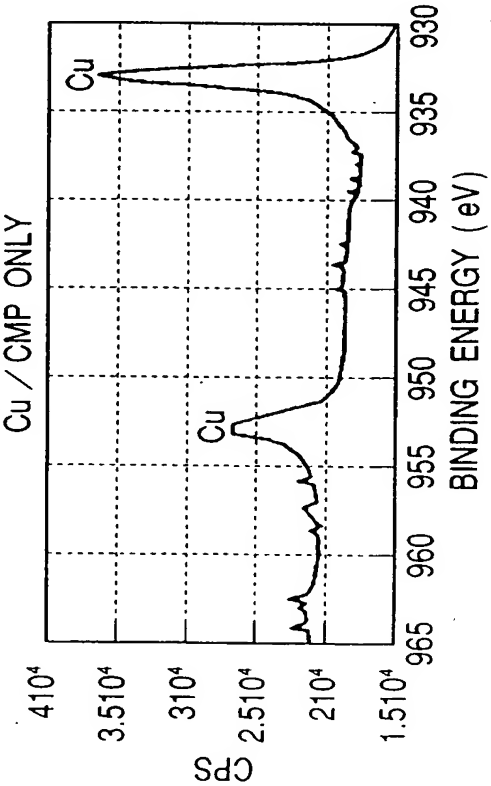


FIG. 22(d)

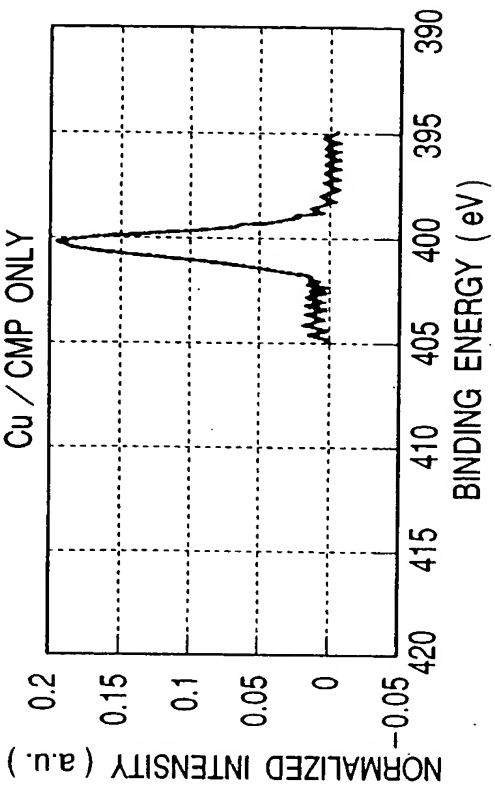


FIG. 23(a)

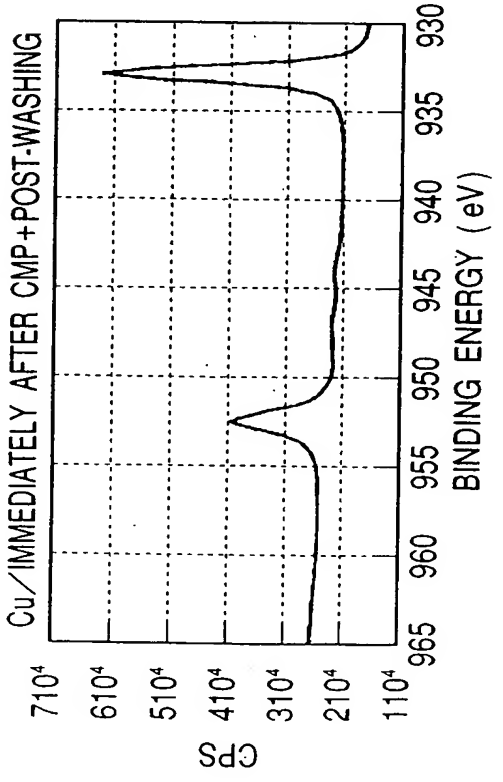


FIG. 23(b)

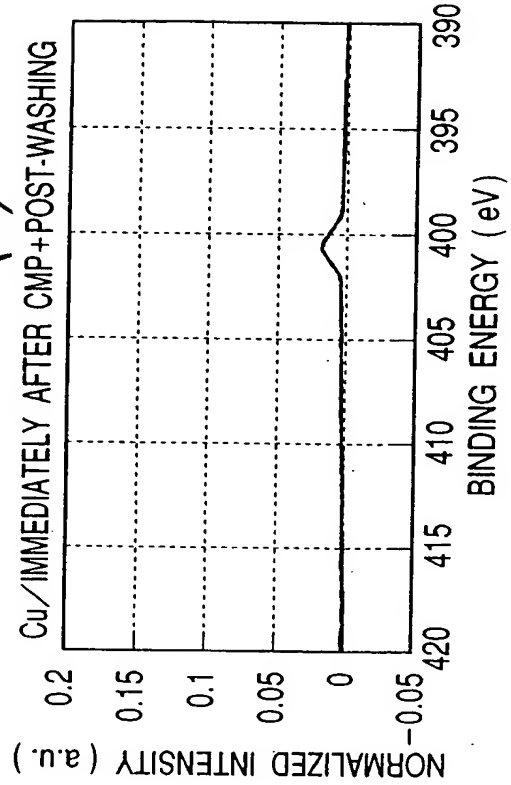


FIG. 23(c)

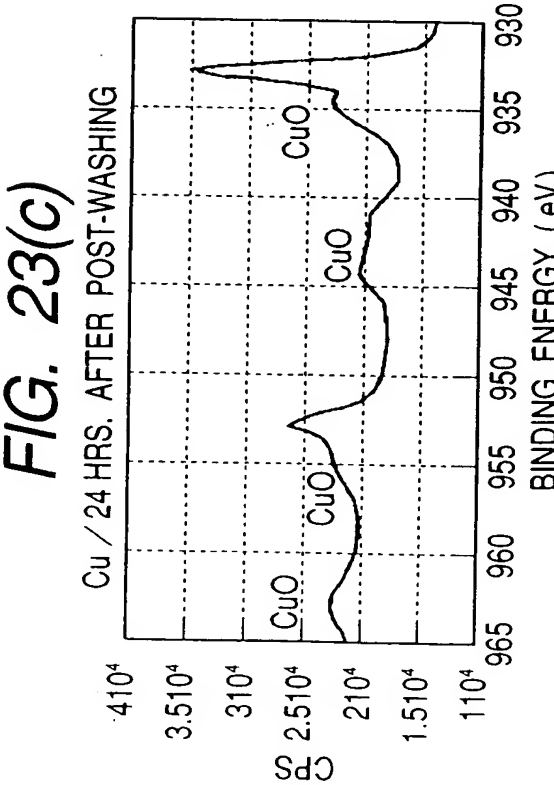


FIG. 23(d)

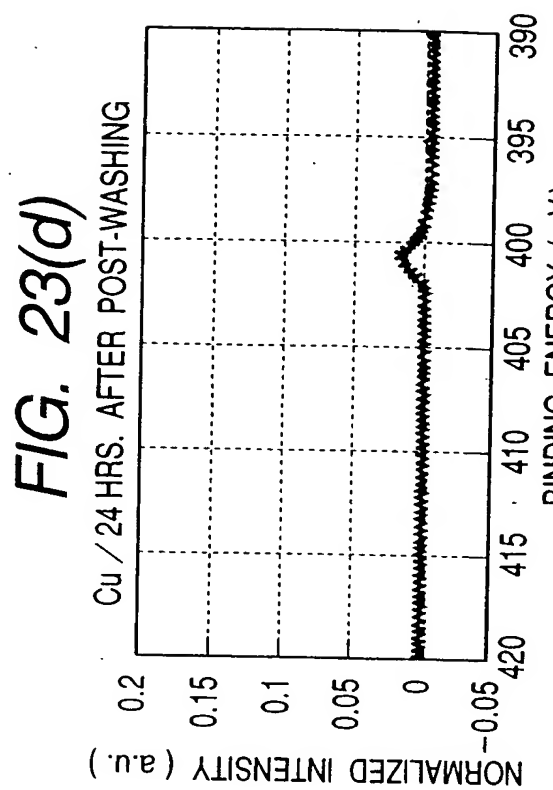


FIG. 24(a)

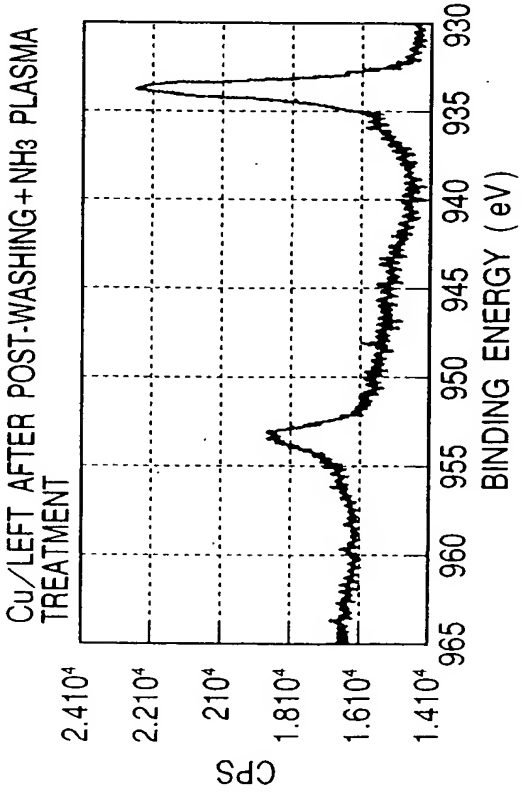


FIG. 24(b)

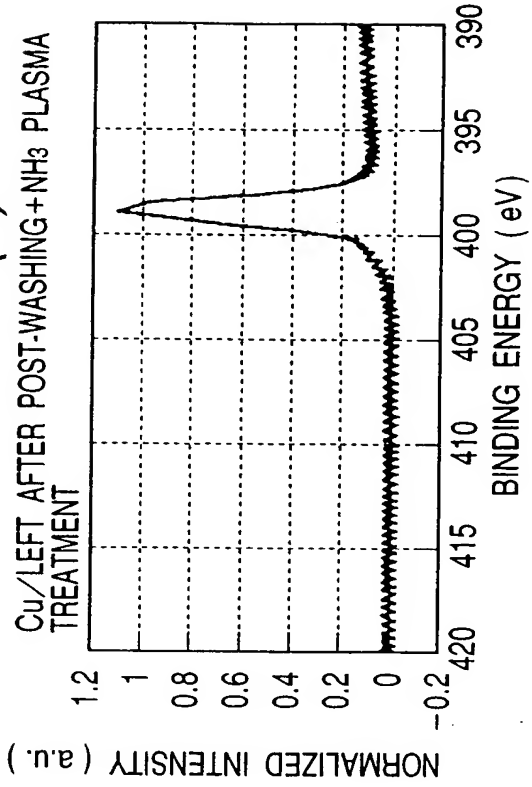


FIG. 24(c)

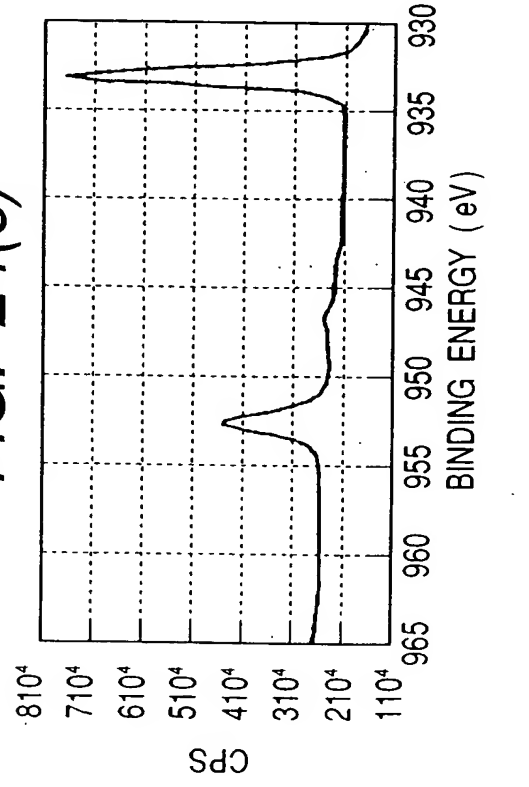


FIG. 24(d)

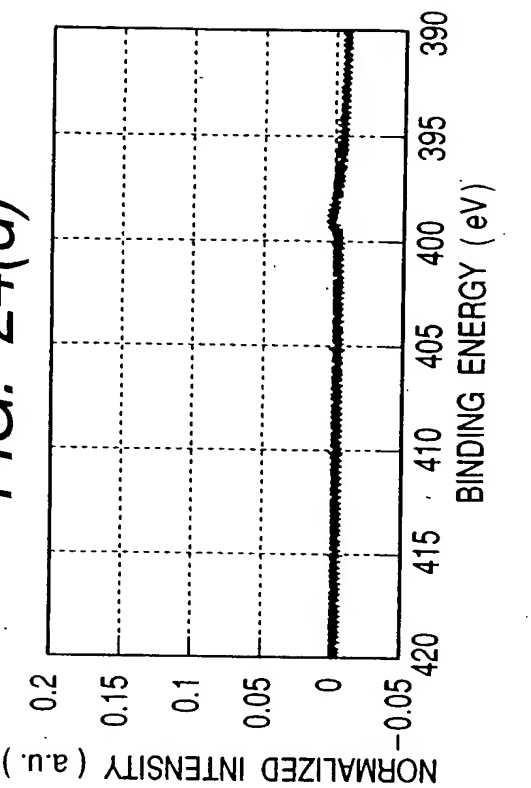


FIG. 25(a)

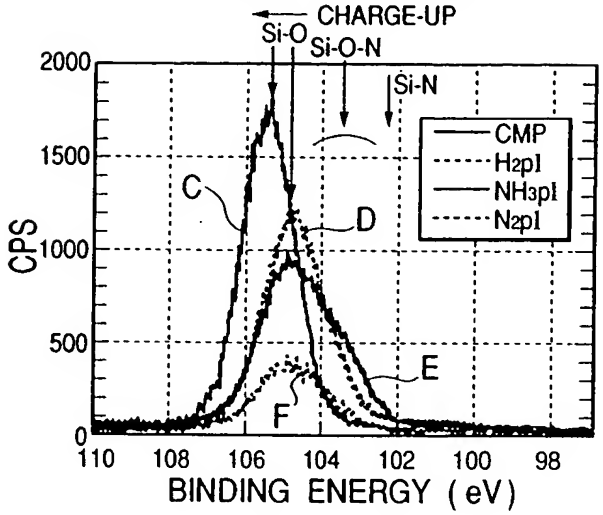


FIG. 25(b)

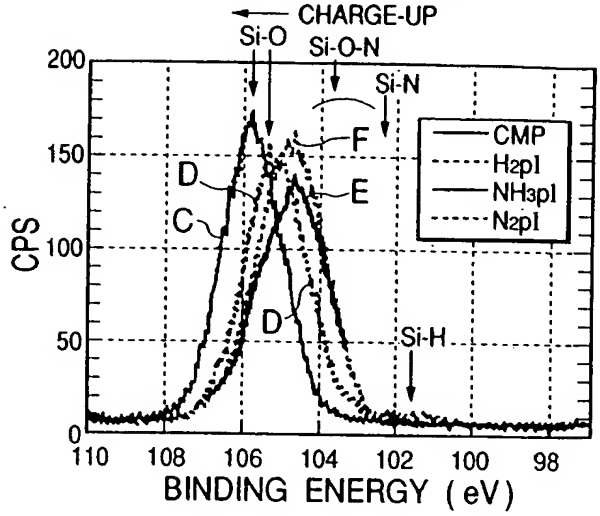


FIG. 25(c)

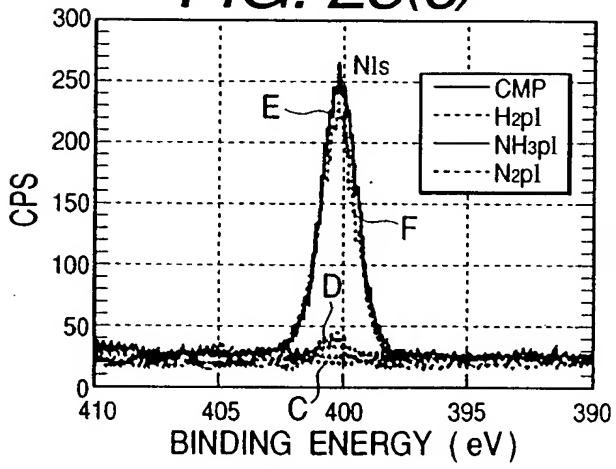


FIG. 25(d)

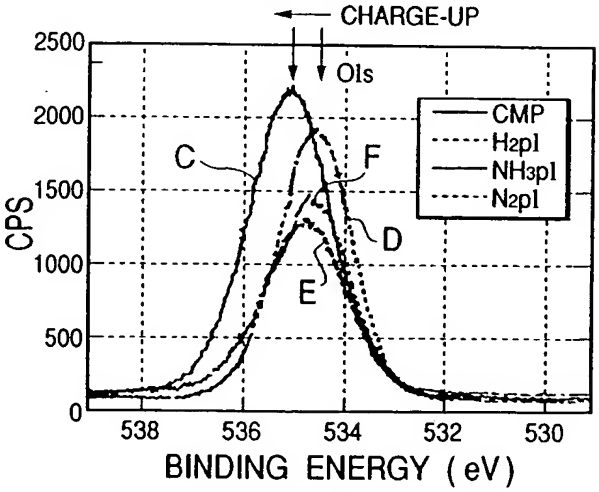


FIG. 25(e)

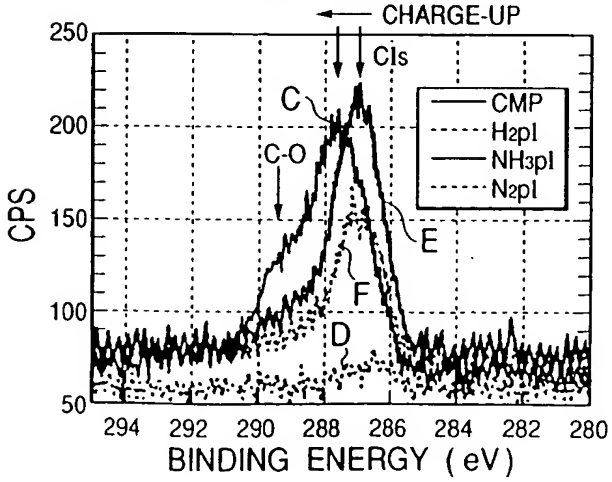
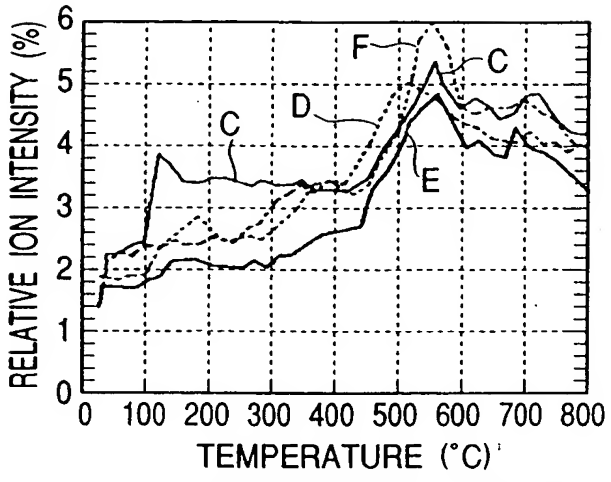


FIG. 25(f)

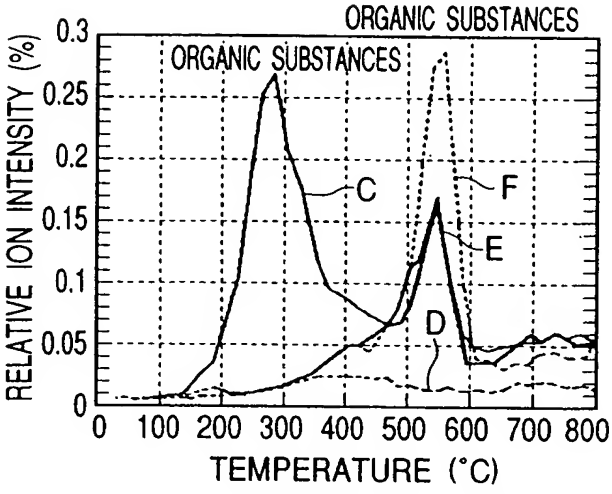
CONDITION	Si3Nx
CMP	—
H2pl	Si3N1.08
NH3pl	Si3N4.22
N2pl	Si3N3.81

FIG. 26(a)



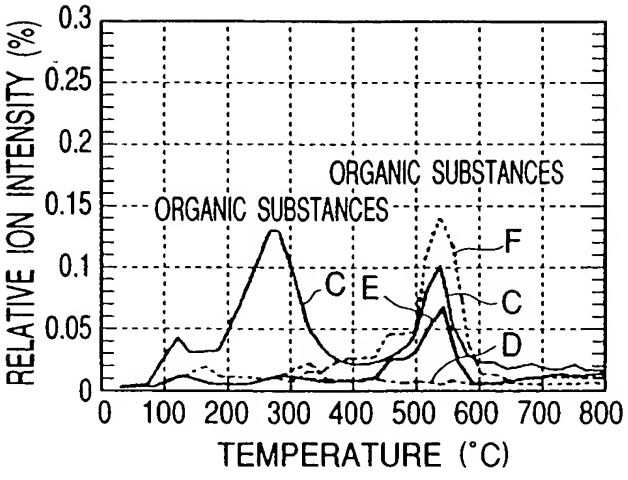
THERMAL DISSOCIATION OF HYDROGEN, Ar−H m/z=41

FIG. 26(b)



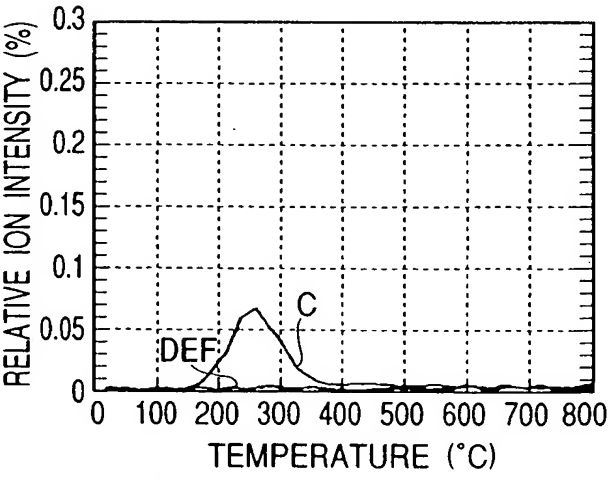
THERMAL DISSOCIATION OF ORGANIC SUBSTANCES, A(CnH2n−1) C2H3 m/z=27

FIG. 26(c)



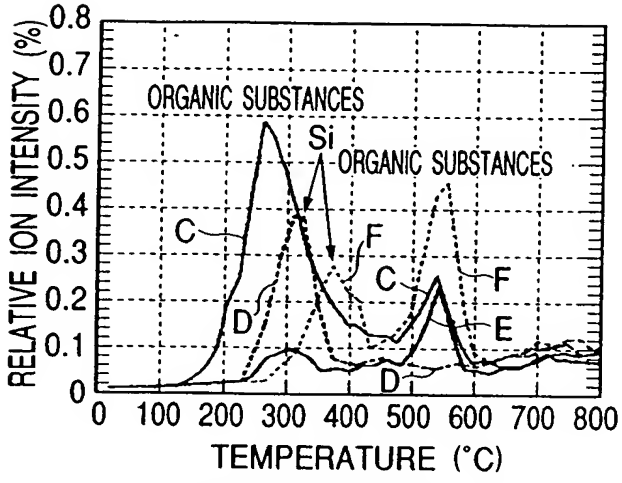
THERMAL DISSOCIATION OF ORGANIC SUBSTANCES, B(CnH2n+1) C4H9 m/z=57

FIG. 26(d)



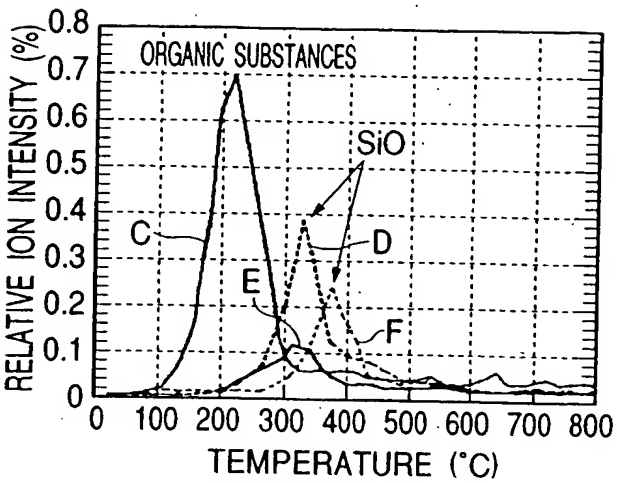
THERMAL DISSOCIATION OF ORGANIC SUBSTANCES, C(CnH2n+1O) C3H7O m/z=59

FIG. 27(a)



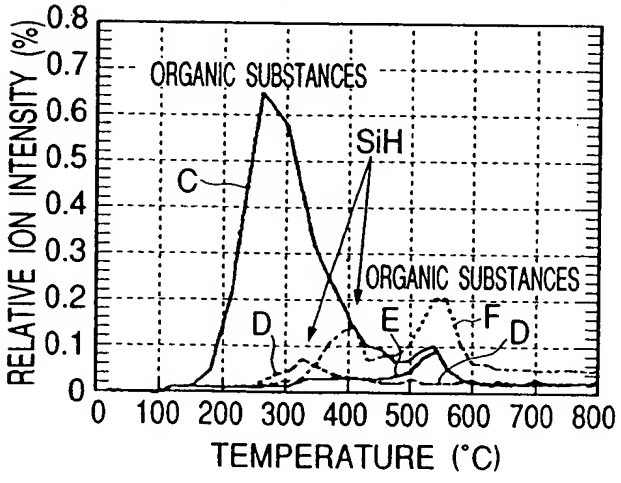
THERMAL DISSOCIATION OF Si AND ORGANIC SUBSTANCES
Si, C2H4 m/z=28

FIG. 27(b)



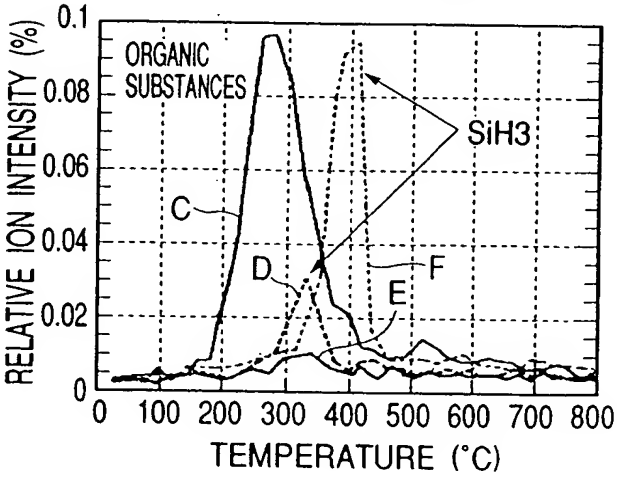
THERMAL DISSOCIATION OF SiO AND ORGANIC SUBSTANCES
SiO, C3H6 m/z=44

FIG. 27(c)



THERMAL DISSOCIATION OF SiH AND ORGANIC SUBSTANCES
SiH, C2H5 m/z=29

FIG. 27(d)



THERMAL DISSOCIATION OF SiH3 AND ORGANIC SUBSTANCES
SiH3 m/z=31

FIG. 28

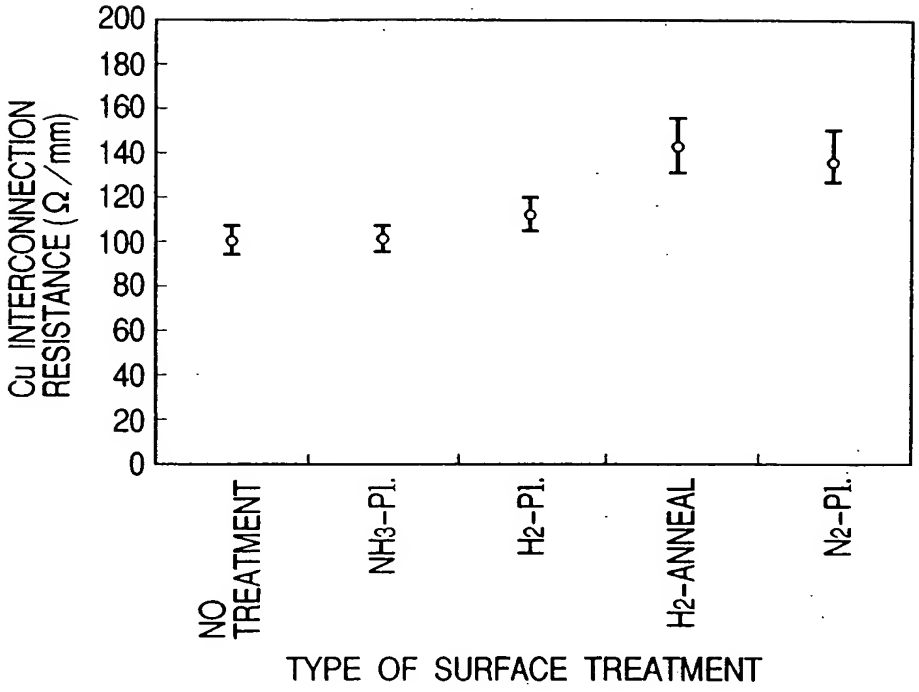

Cu INTERCONNECTION RESISTANCE (Ω/mm)
200
180
160
140
120
100
80
60
40
20
0
NO TREATMENT
NH3-Pl.
H2-Pl.
H2-ANNEAL
N2-Pl.
TYPE OF SURFACE TREATMENT

FIG. 29

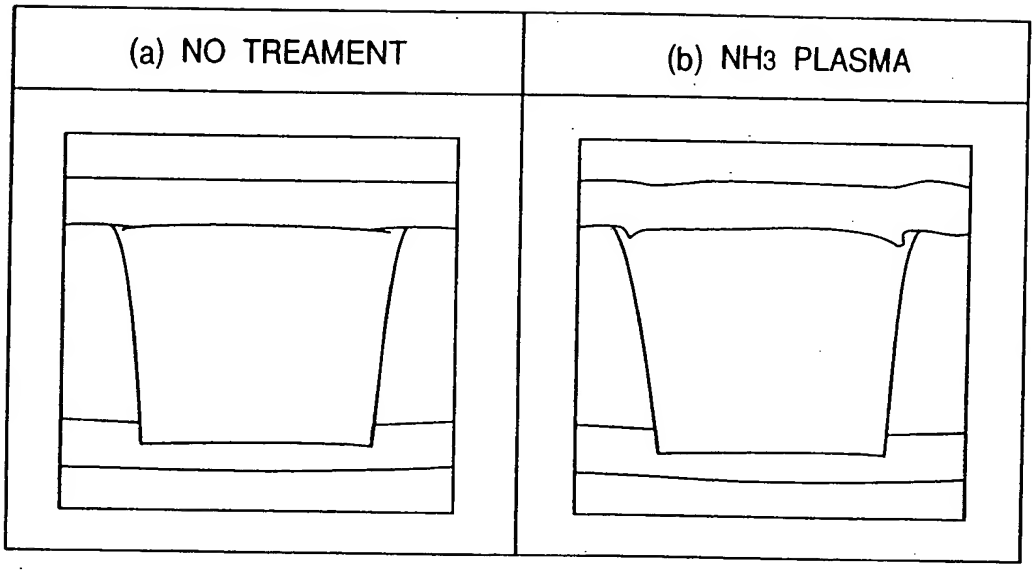


FIG. 30

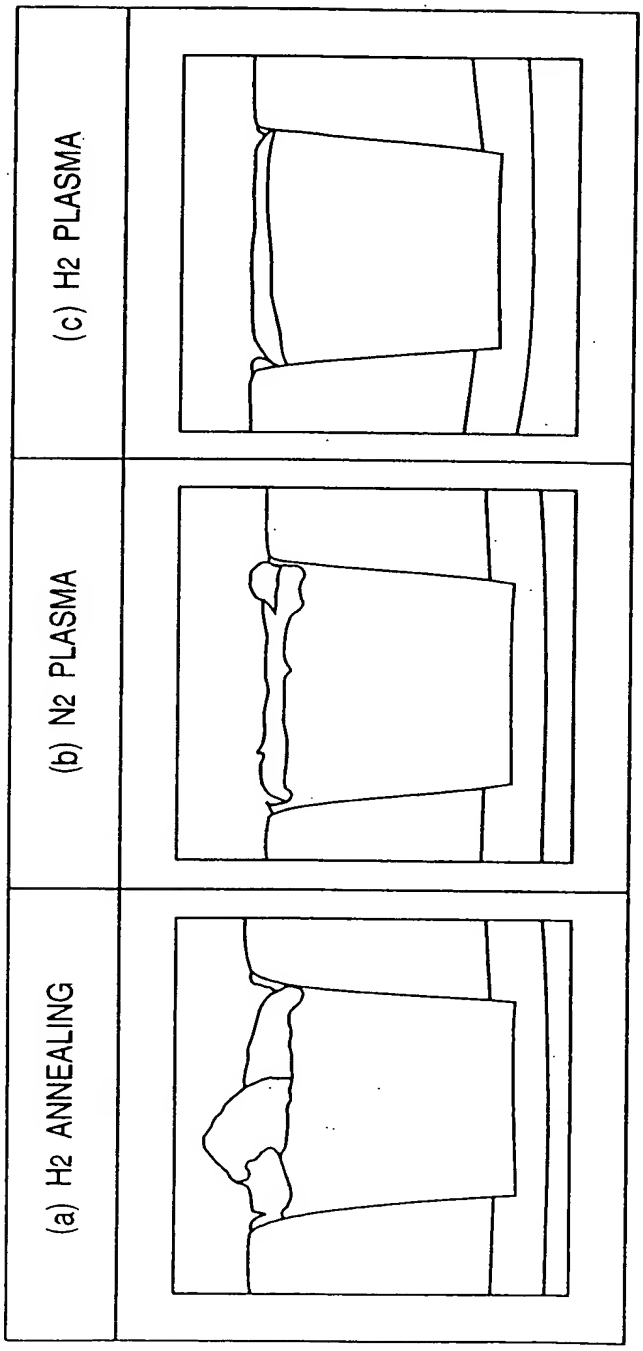


FIG. 31(a)

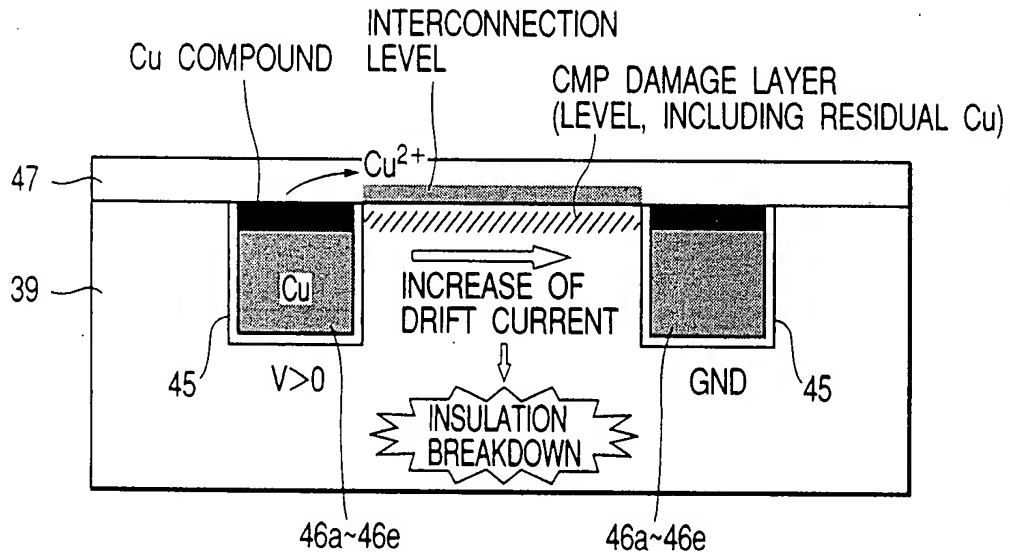


FIG. 31(b)

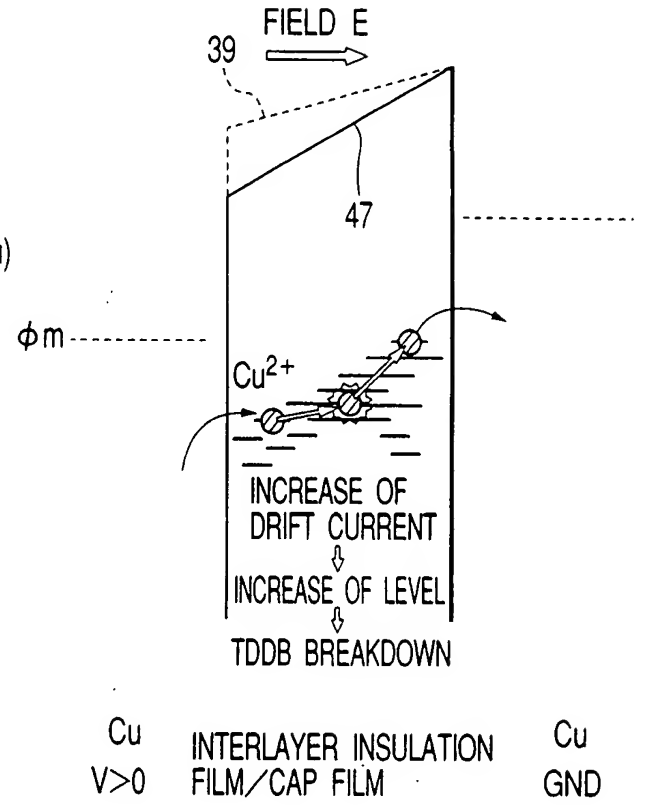


FIG. 32(a)

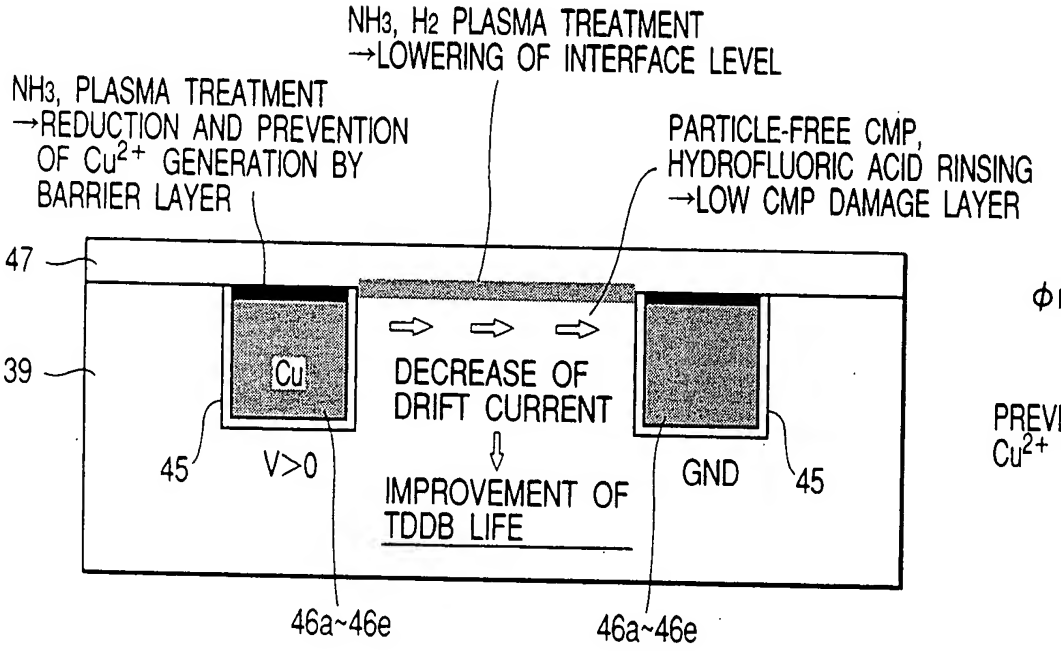


FIG. 32(b)

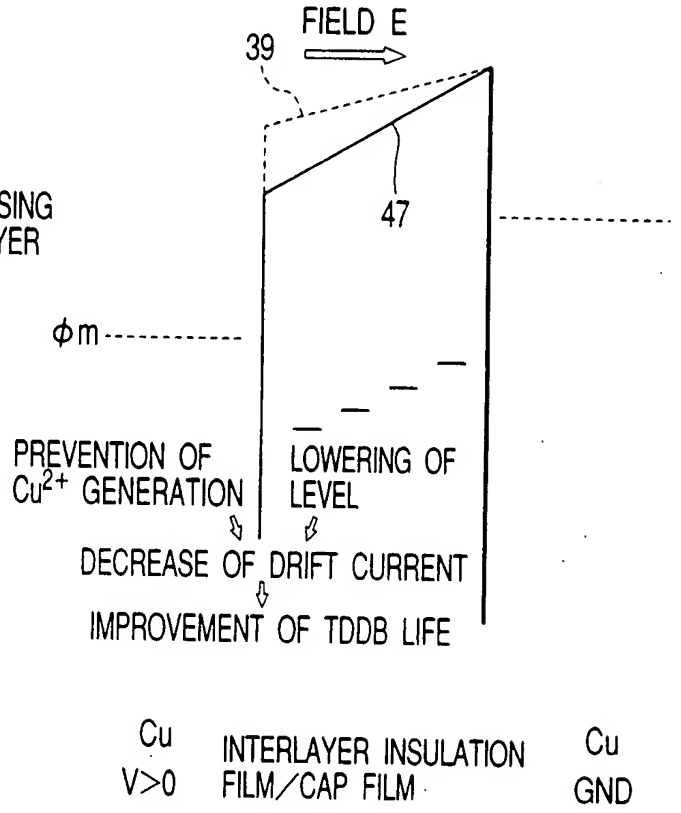


FIG. 33

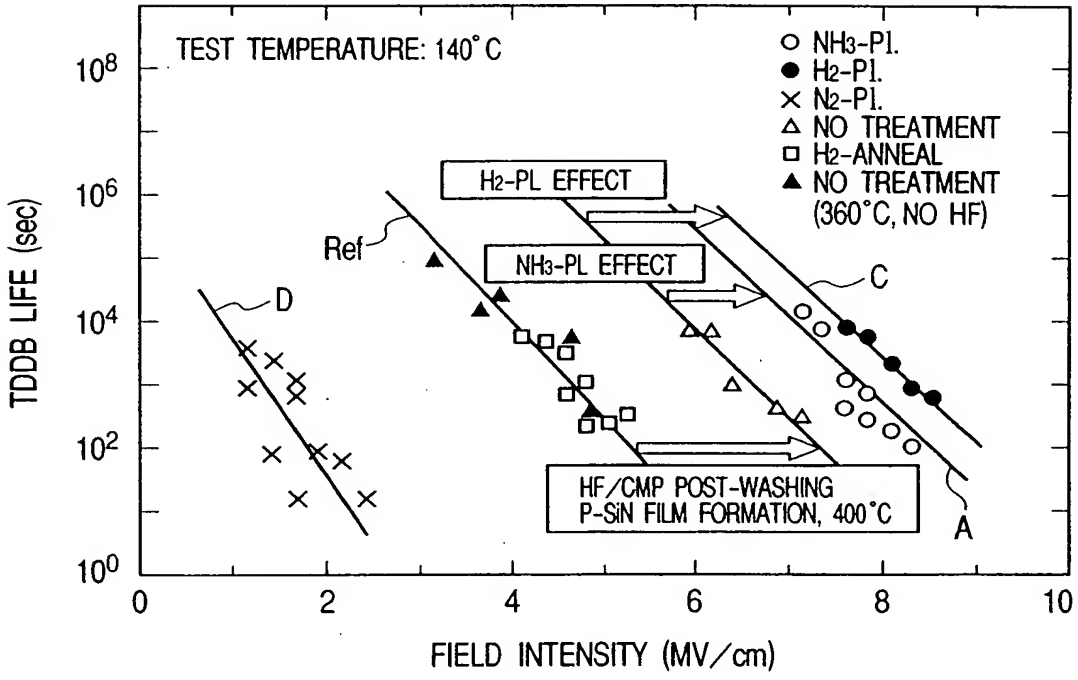

TEST TEMPERATURE: 140°C
NH3-Pl.
H2-Pl.
N2-Pl.
NO TREATMENT
H2-ANNEAL
NO TREATMENT (360°C, NO HF)
H2-PL EFFECT
NH3-PL EFFECT
Ref
C
D
A
HF/CMP POST-WASHING P-SiN FILM FORMATION, 400°C
TDDB LIFE (sec)
FIELD INTENSITY (MV/cm)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10

FIG. 34

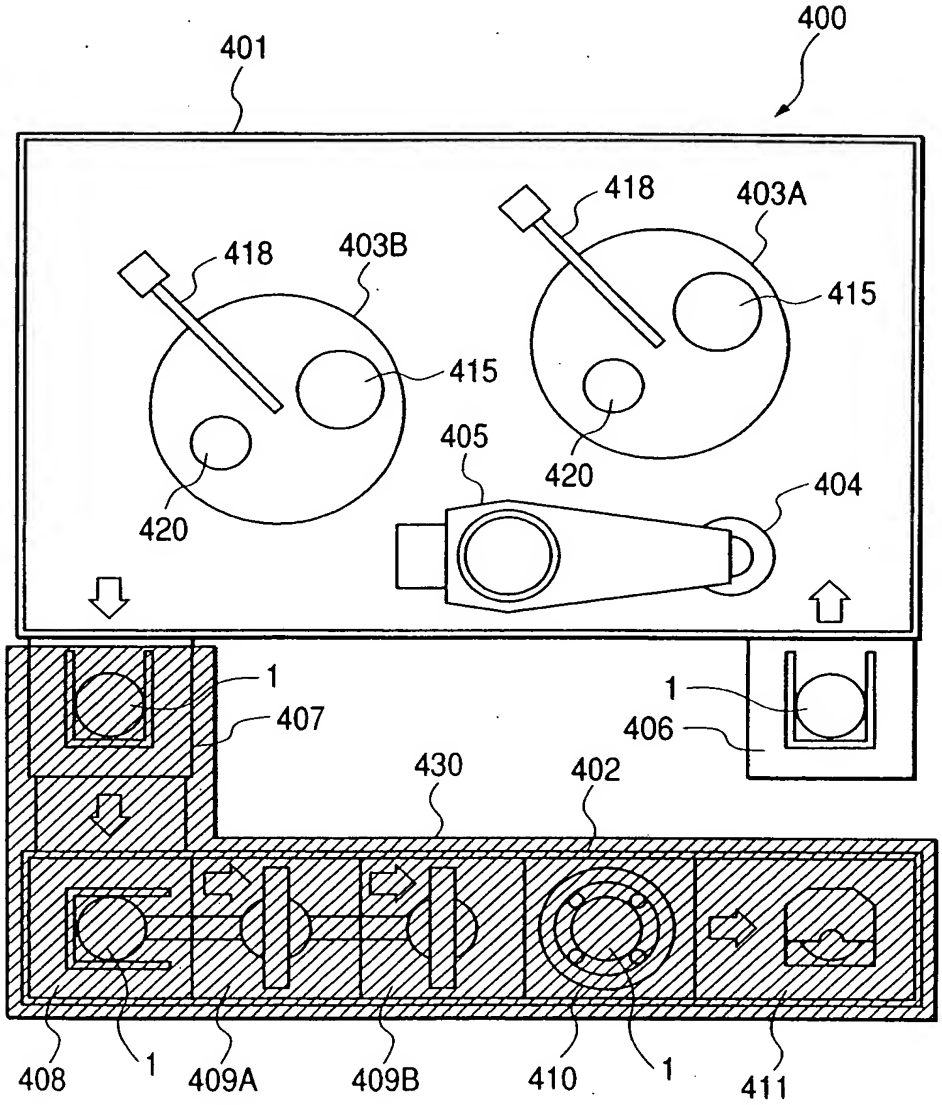

400
401
418
403A
415
418
403B
415
405
420
420
404
1
407
1
406
430
402
408
1
409A
409B
410
1
411

FIG. 35

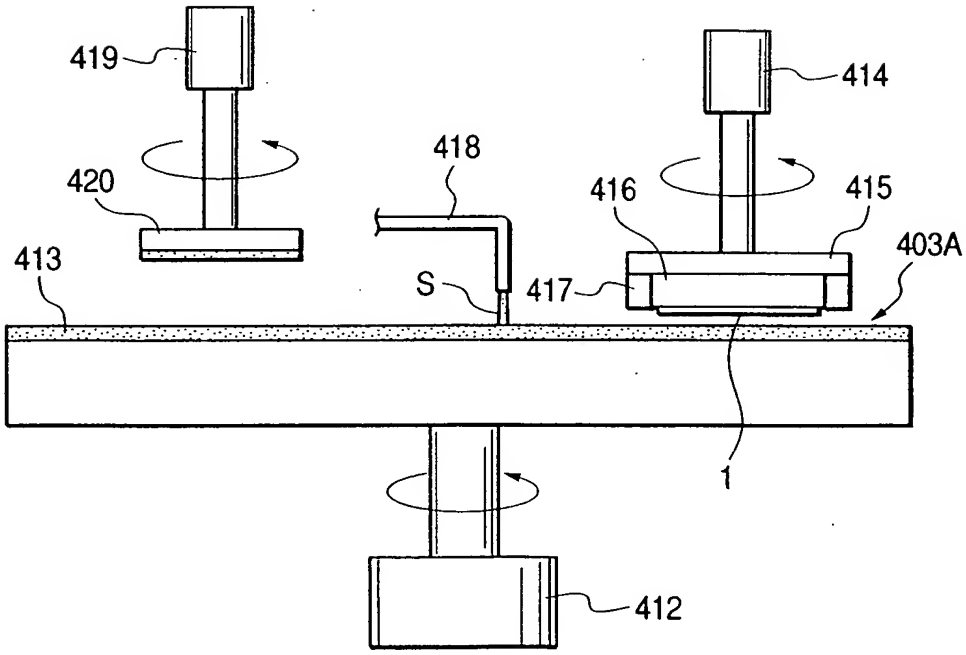


FIG. 36

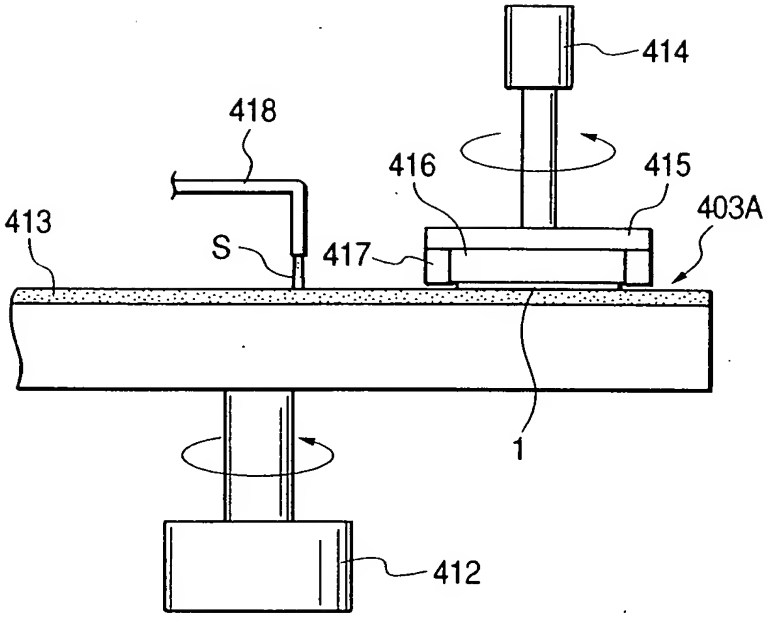


FIG. 37

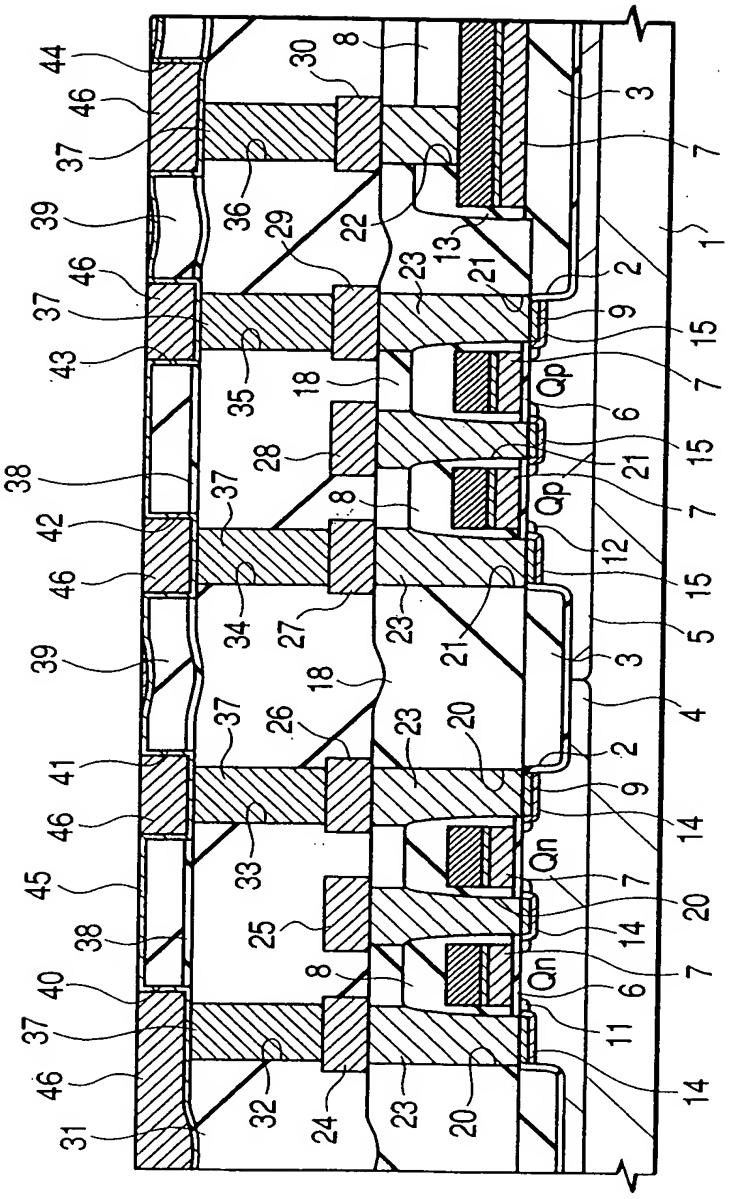


FIG. 38(a)

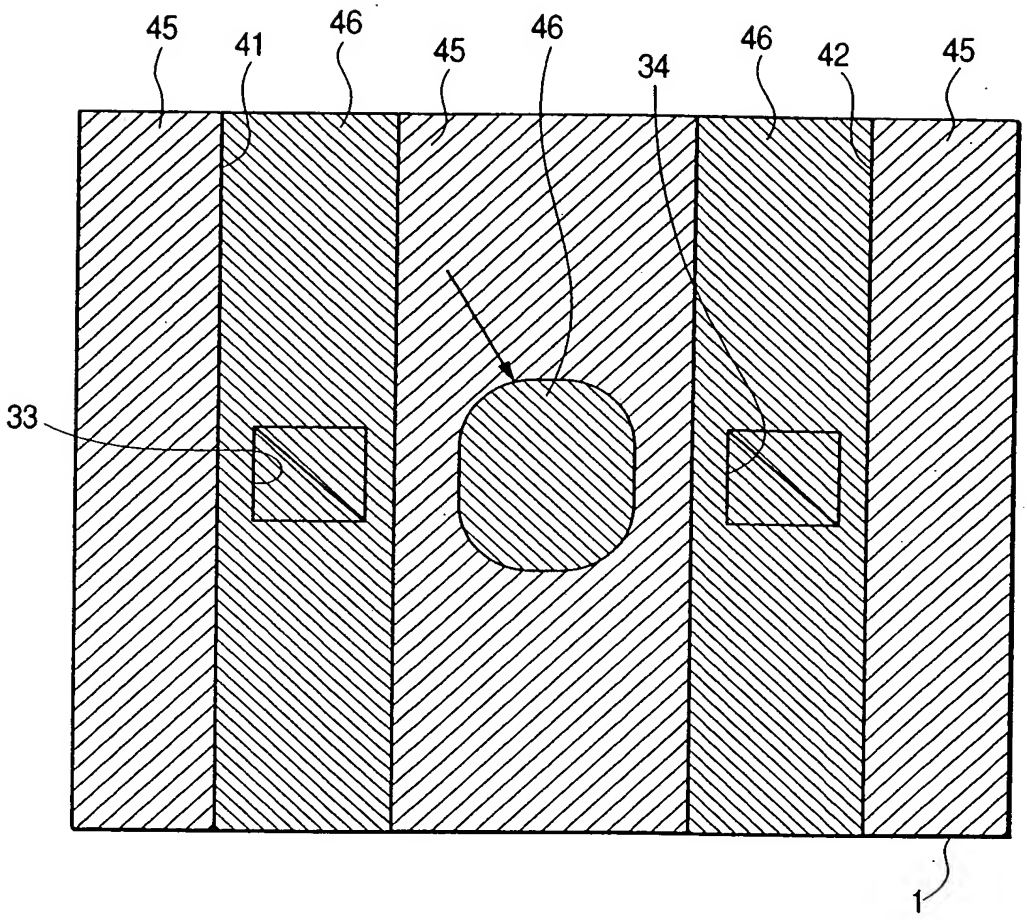


FIG. 38(b)

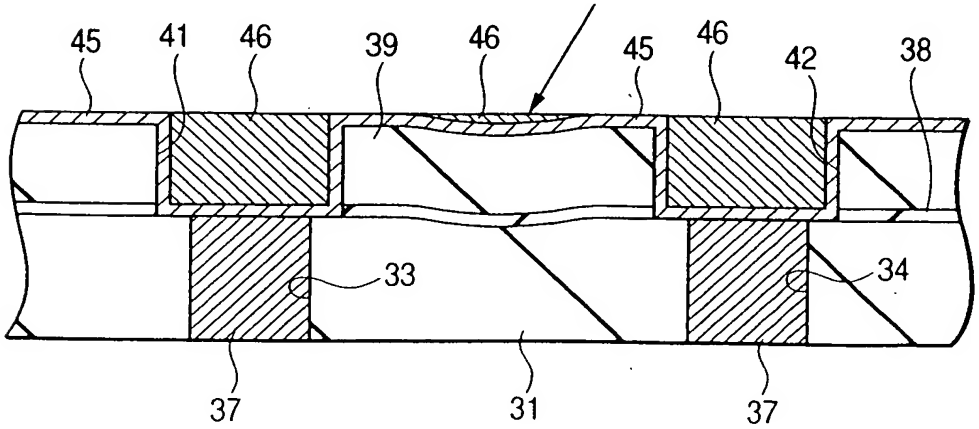


FIG. 39

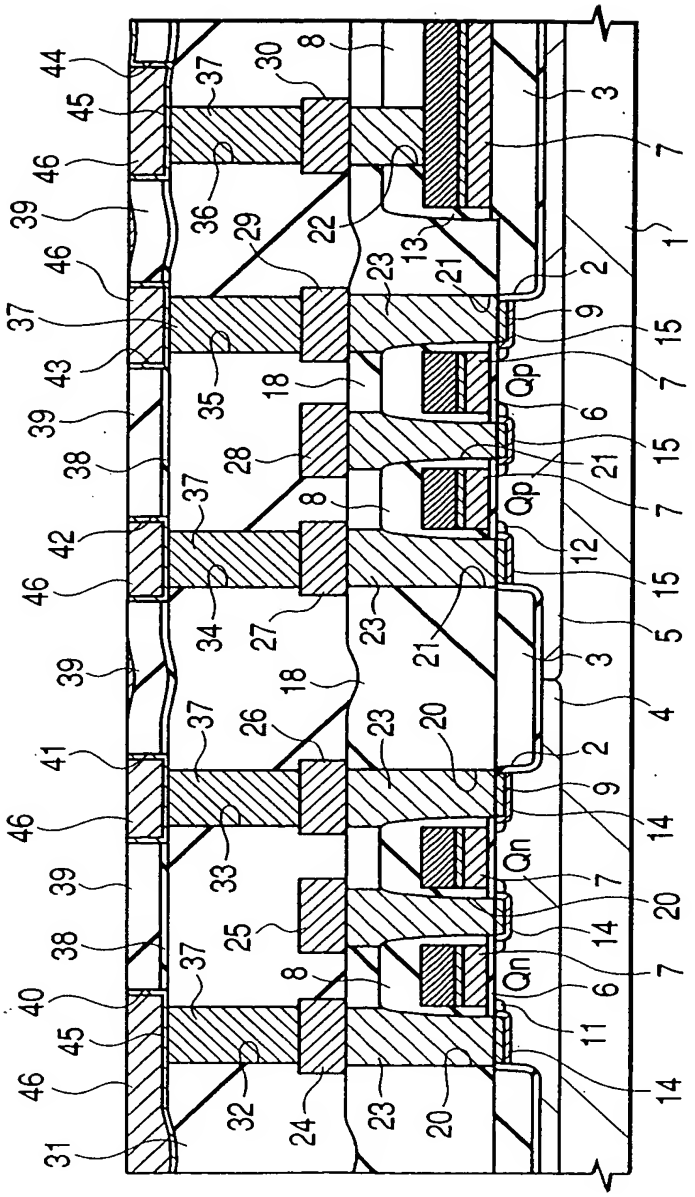


FIG. 40(a)

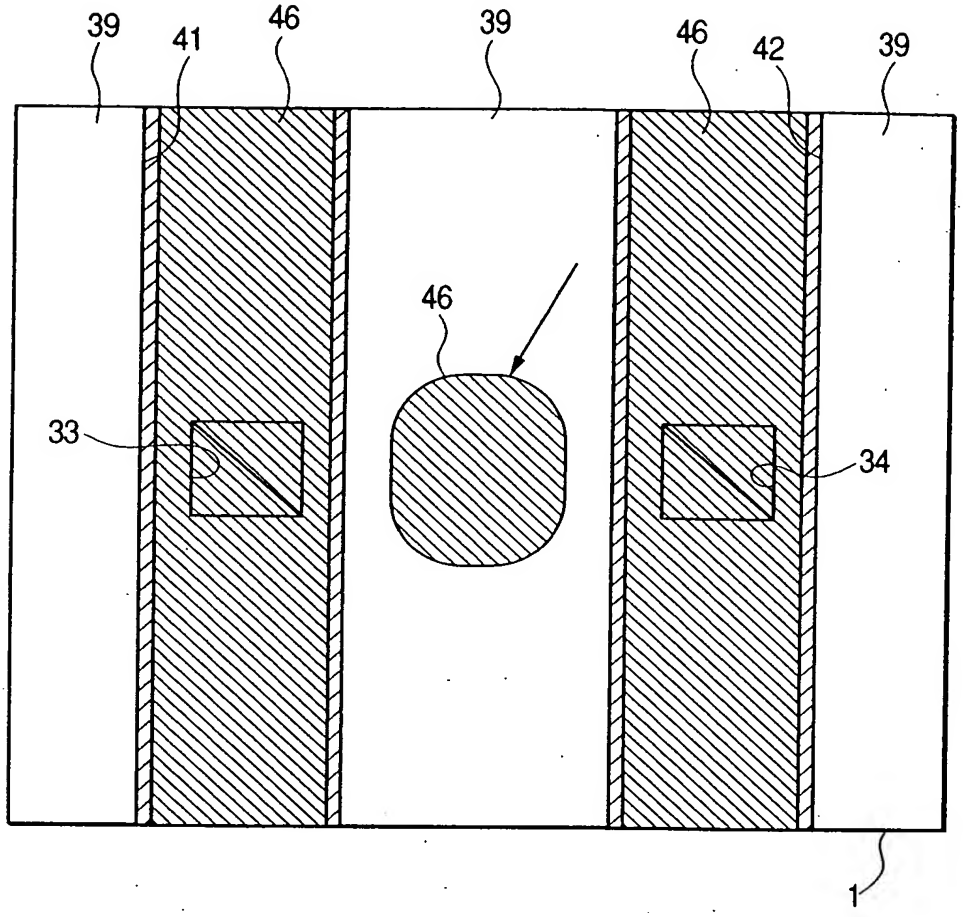


FIG. 40(b)

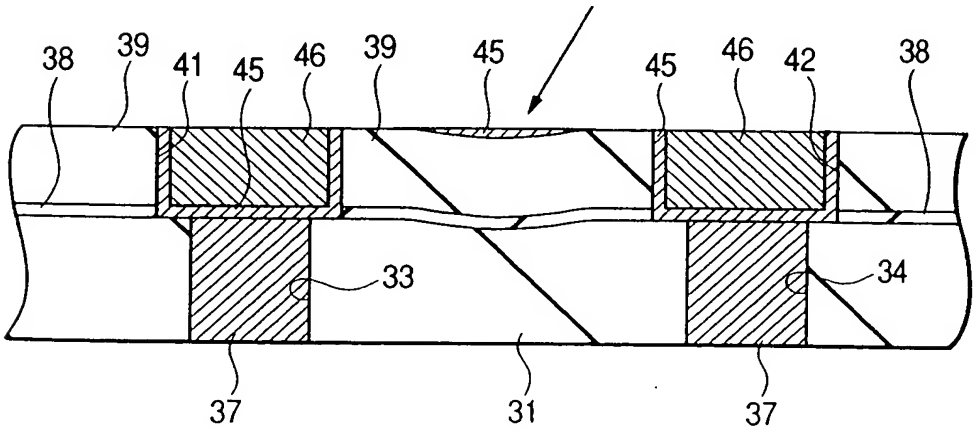


FIG. 41

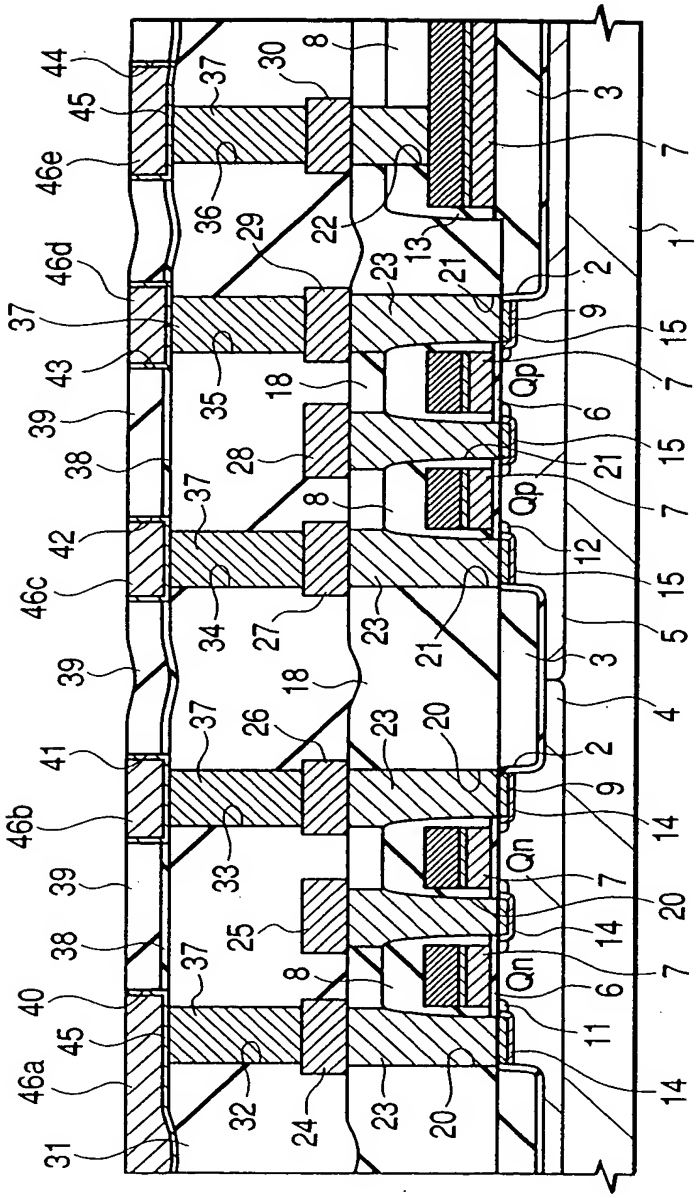


FIG. 42(a)

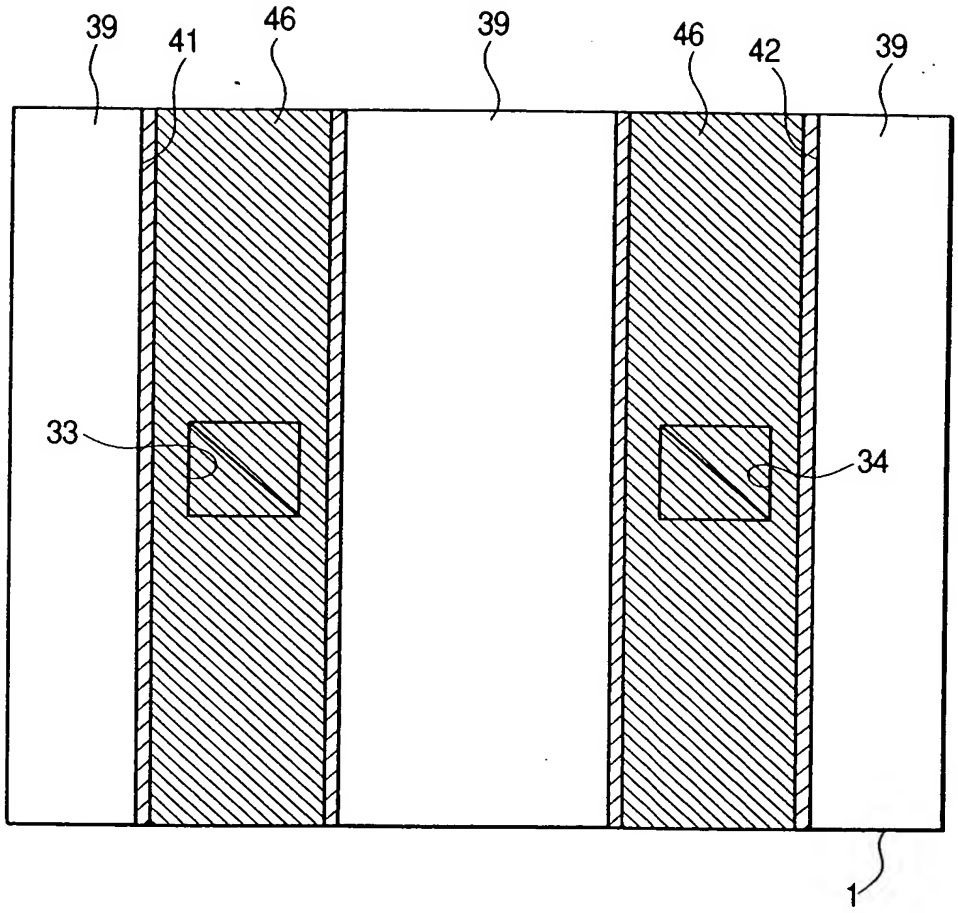


FIG. 42(b)

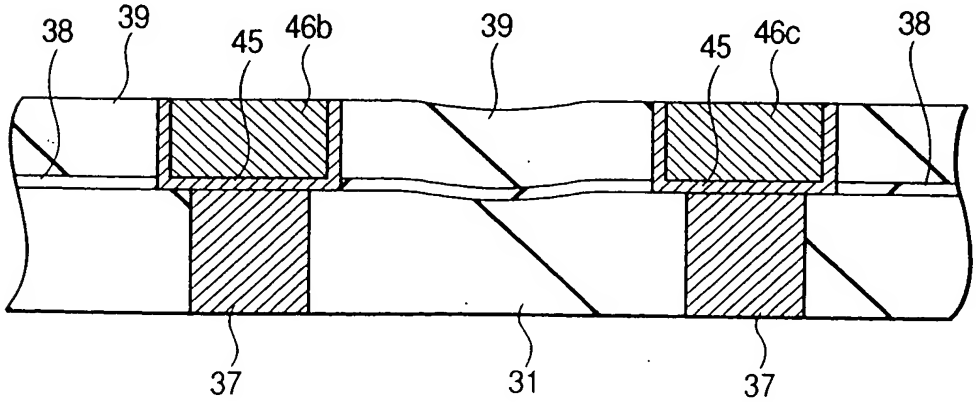


FIG. 43

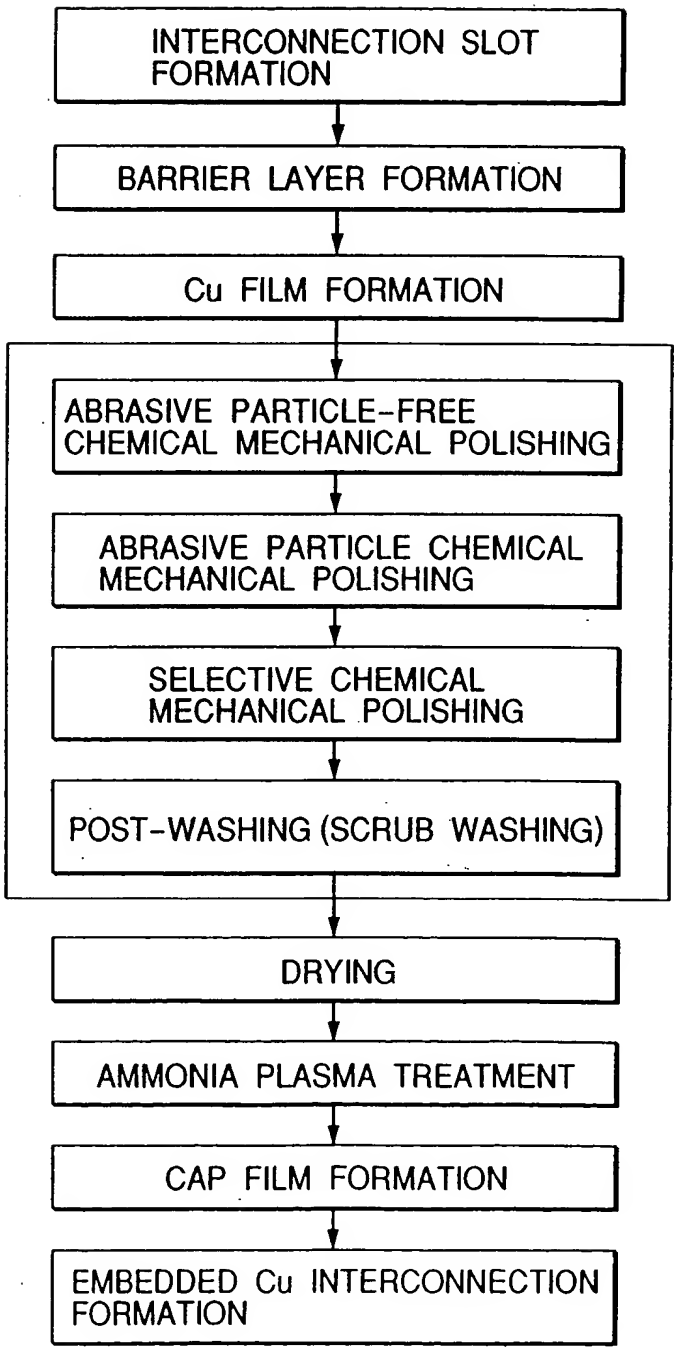

INTERCONNECTION SLOT FORMATION
BARRIER LAYER FORMATION
Cu FILM FORMATION
ABRASIVE PARTICLE-FREE CHEMICAL MECHANICAL POLISHING
ABRASIVE PARTICLE CHEMICAL MECHANICAL POLISHING
SELECTIVE CHEMICAL MECHANICAL POLISHING
POST-WASHING (SCRUB WASHING)
DRYING
AMMONIA PLASMA TREATMENT
CAP FILM FORMATION
EMBEDDED Cu INTERCONNECTION FORMATION

FIG. 44

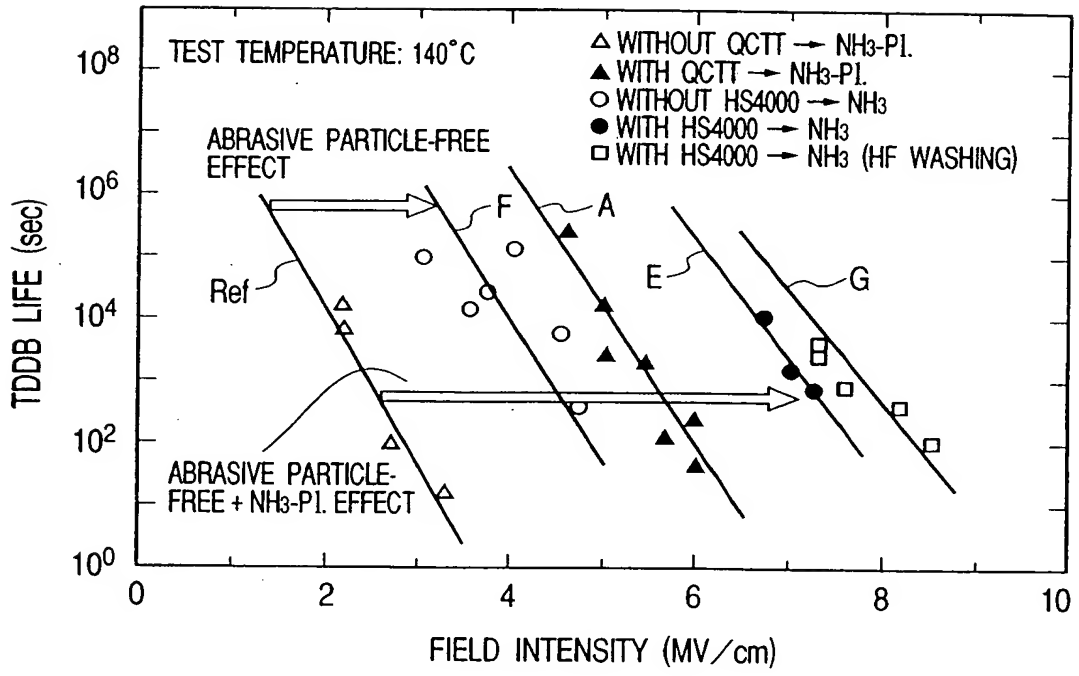

TEST TEMPERATURE: 140°C
△ WITHOUT QCTT → NH3-P1.
▲ WITH QCTT → NH3-P1.
○ WITHOUT HS4000 → NH3
● WITH HS4000 → NH3
□ WITH HS4000 → NH3 (HF WASHING)
ABRASIVE PARTICLE-FREE EFFECT
F
A
E
G
Ref
ABRASIVE PARTICLE-FREE + NH3-P1. EFFECT
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10
FIELD INTENSITY (MV/cm)

FIG. 45

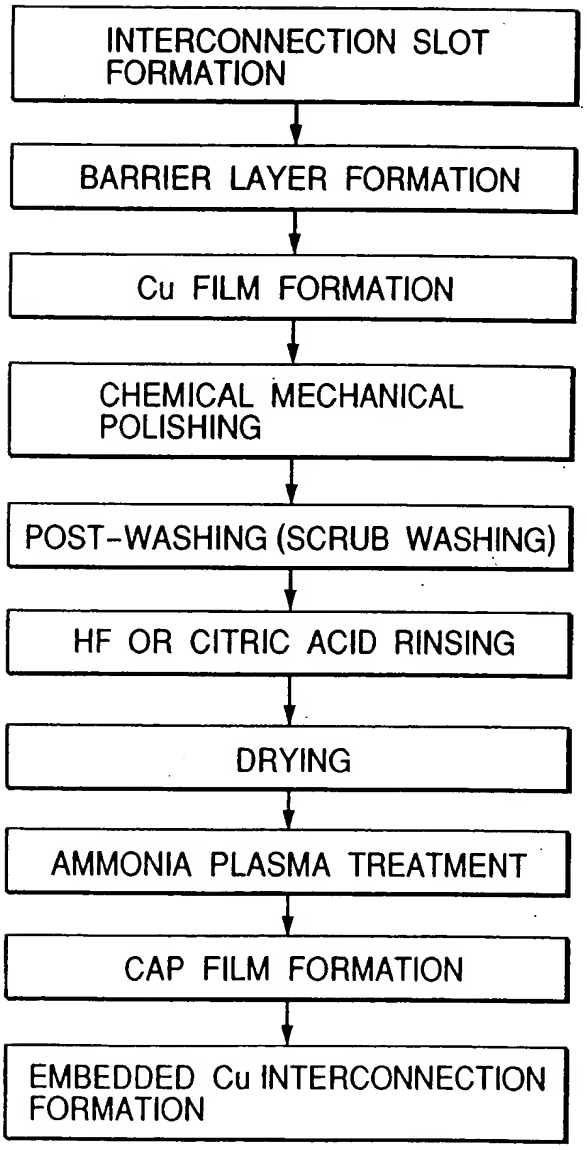

INTERCONNECTION SLOT FORMATION
BARRIER LAYER FORMATION
Cu FILM FORMATION
CHEMICAL MECHANICAL POLISHING
POST-WASHING (SCRUB WASHING)
HF OR CITRIC ACID RINSING
DRYING
AMMONIA PLASMA TREATMENT
CAP FILM FORMATION
EMBEDDED Cu INTERCONNECTION FORMATION

FIG. 46

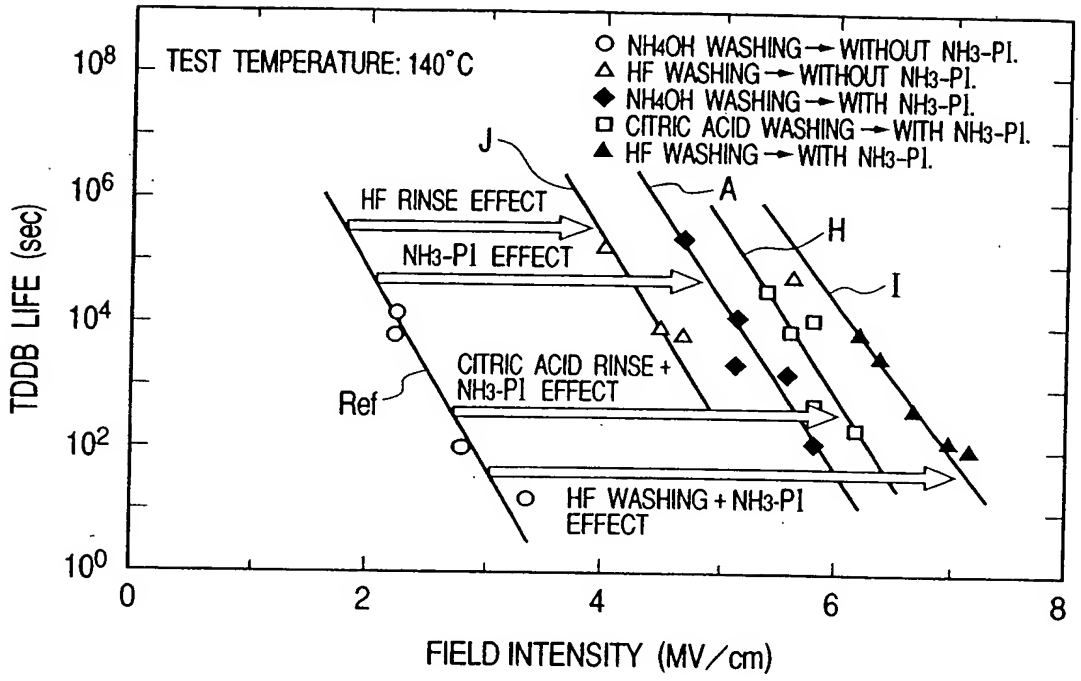

TEST TEMPERATURE: 140°C
NH4OH WASHING → WITHOUT NH3-PI.
HF WASHING → WITHOUT NH3-PI.
NH4OH WASHING → WITH NH3-PI.
CITRIC ACID WASHING → WITH NH3-PI.
HF WASHING → WITH NH3-PI.
J
A
H
I
HF RINSE EFFECT
NH3-PI EFFECT
CITRIC ACID RINSE + NH3-PI EFFECT
Ref
HF WASHING + NH3-PI EFFECT
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
FIELD INTENSITY (MV/cm)

FIG. 47

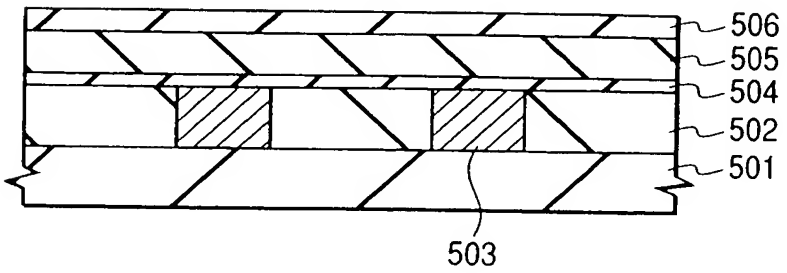

506
505
504
502
501
503

FIG. 48(a)

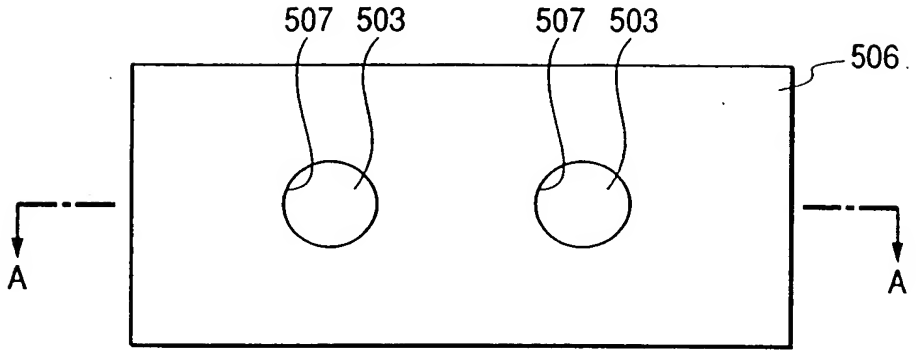


FIG. 48(b)

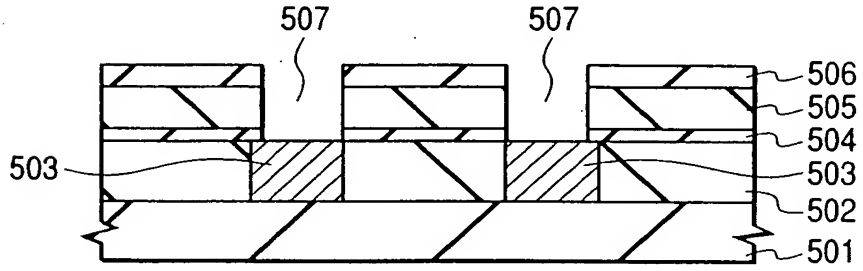
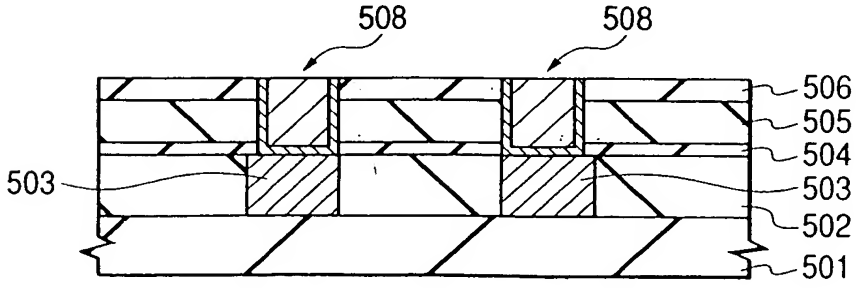


FIG. 49



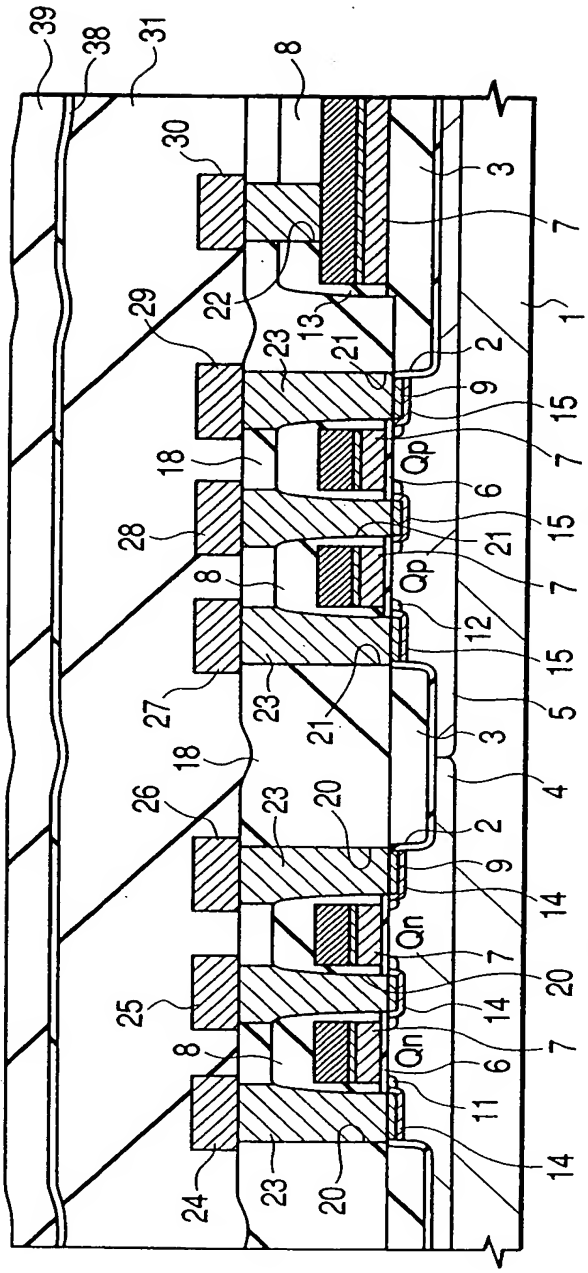

39
38
31
8
30
3
7
1
29
22
23
13
21
2
9
15
18
Qp
6
28
21
7
8
12
27
5
23
21
3
18
4
26
23
20
2
9
14
Qn
7
25
20
14
8
7
6
11
24
23
20
14

FIG. 50

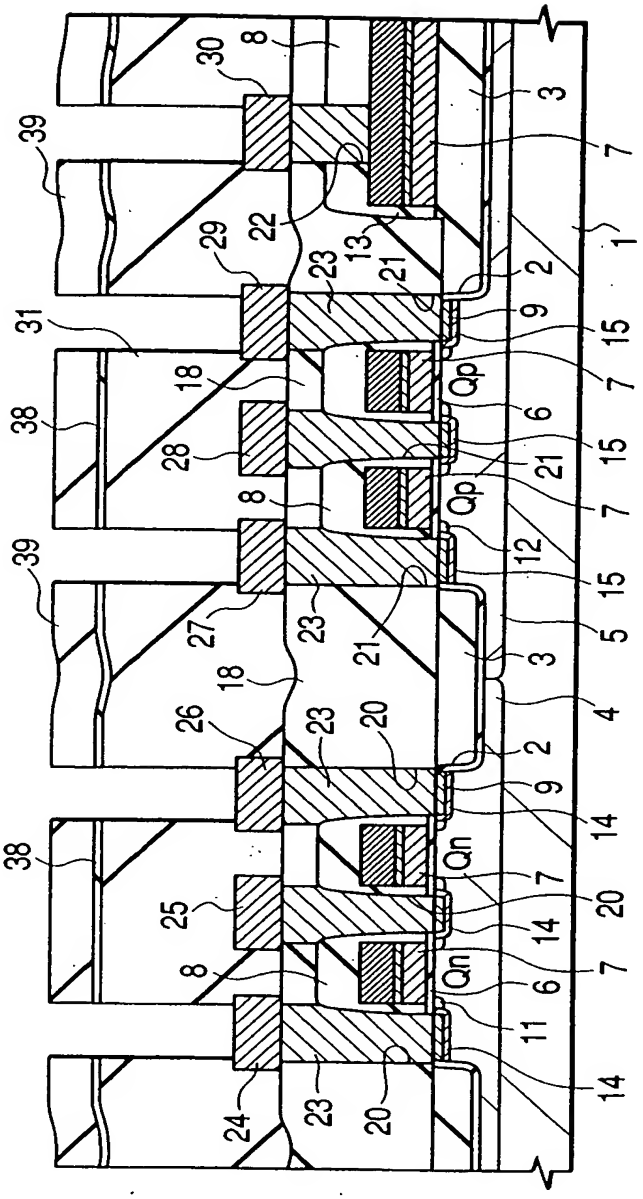

30
8
3
7
39
1
29
22
23
13
21
2
9
31
15
18
Qp
7
6
38
28
21
15
8
7
12
39
15
27
23
21
5
3
18
4
26
23
20
2
9
14
38
Qn
7
25
20
14
8
7
6
11
24
23
20
14

FIG. 51

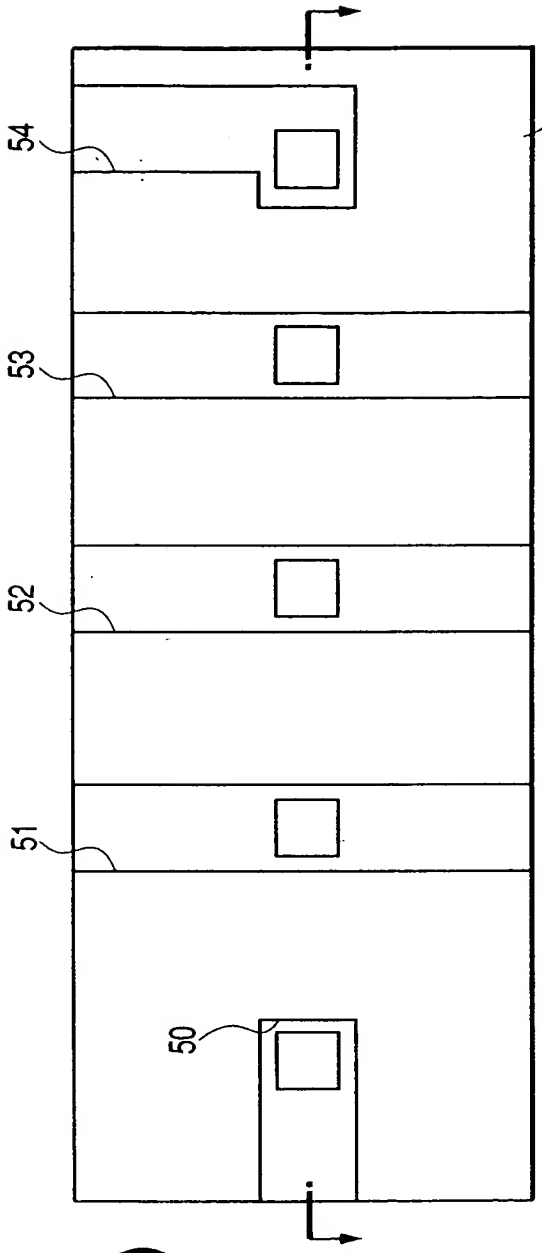


FIG. 52(a)

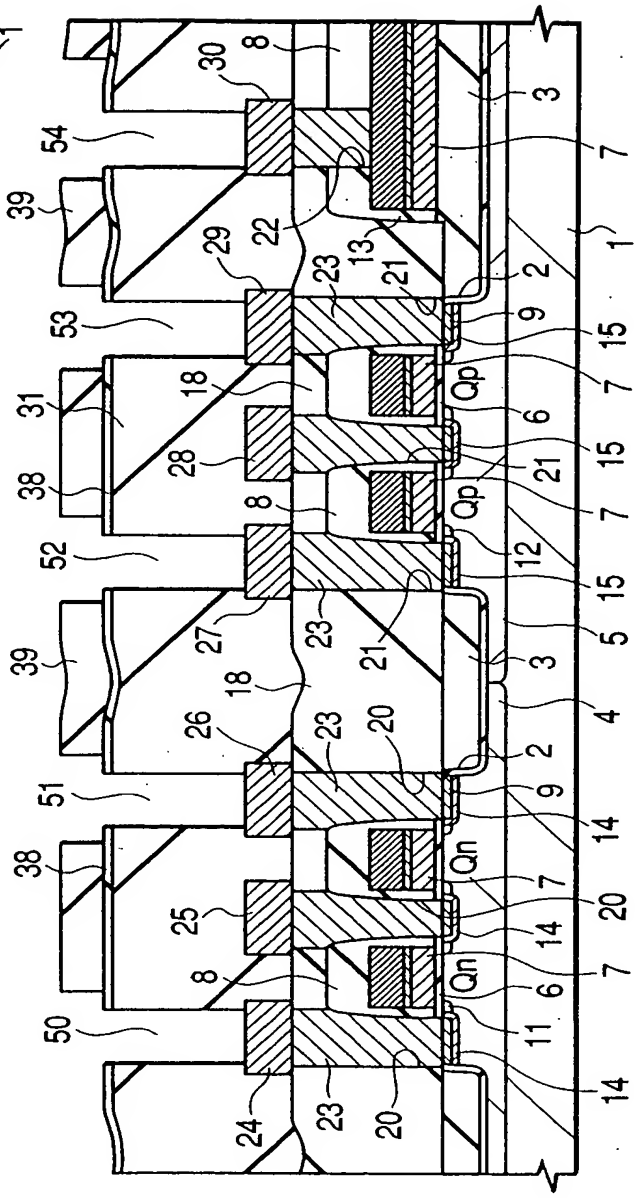


FIG. 52(b)

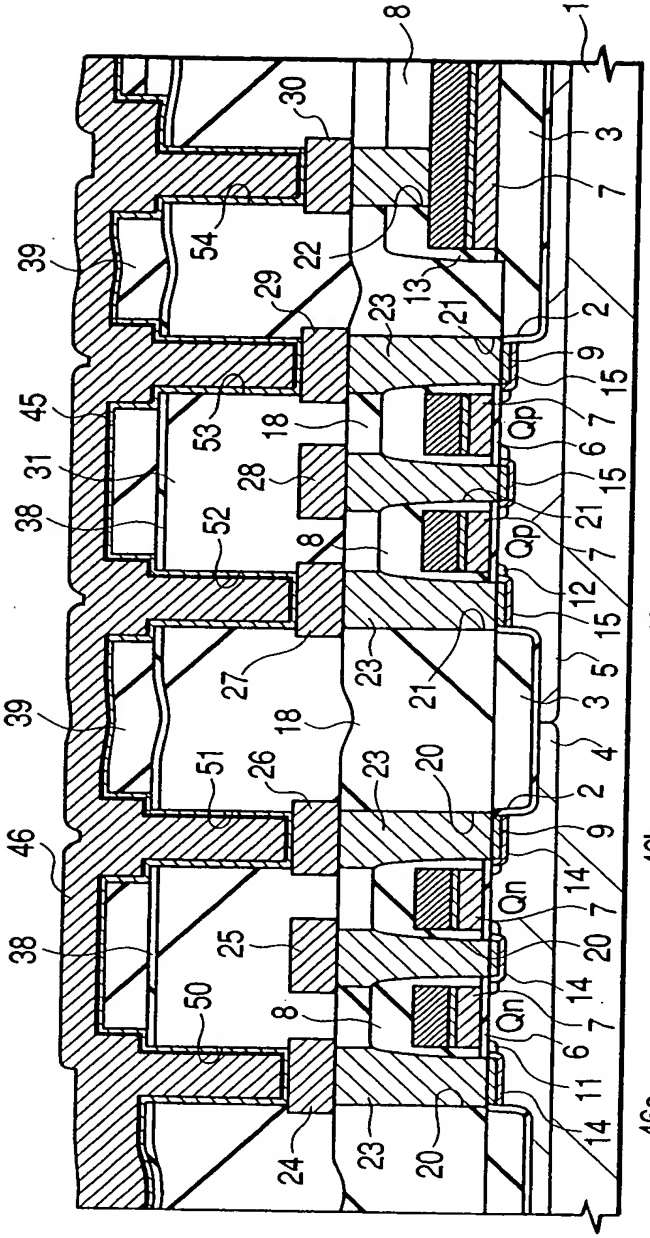

1
8
30
3
7
39
54
22
29
13
23
21
2
9
15
45
53
18
Qp
6
7
31
28
15
38
52
8
21
Qp
7
12
15
27
23
21
3
5
39
18
51
26
23
20
2
4
9
46
14
38
Qn
7
25
20
50
14
8
Qn
7
6
11
14
24
23
20

FIG. 53

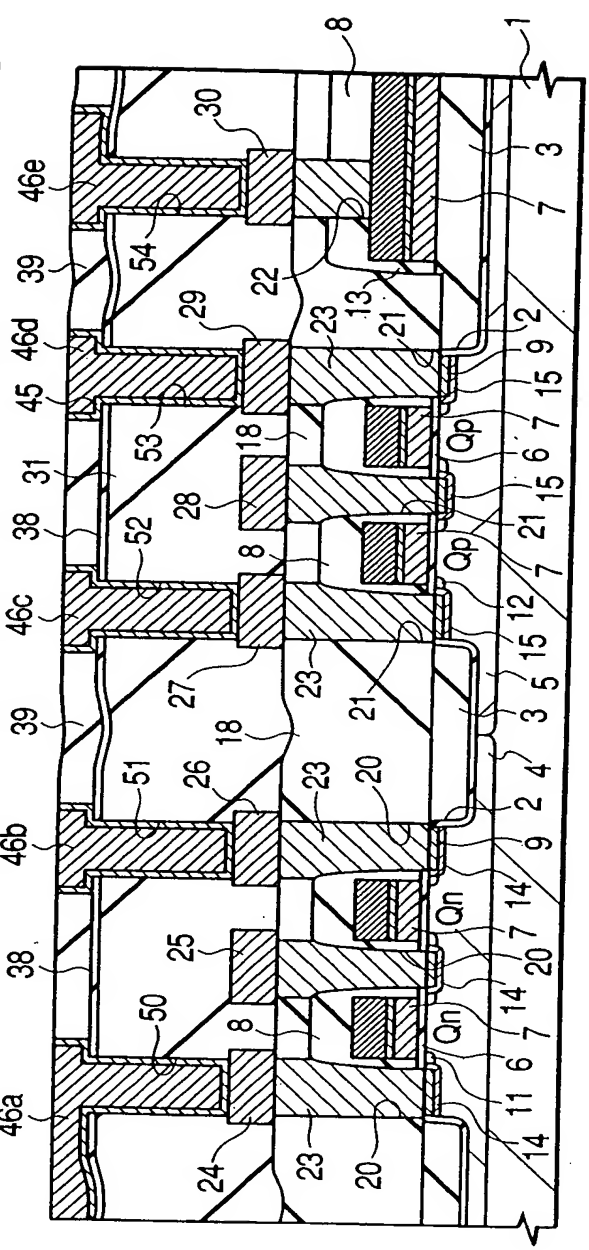

1
8
30
46e
3
7
39
54
22
29
13
23
21
2
46d
9
15
45
53
18
Qp
6
7
31
28
15
38
52
8
21
Qp
7
46c
12
15
27
23
21
3
5
39
18
51
26
23
20
2
4
9
46b
14
38
Qn
7
25
20
50
14
8
Qn
7
6
11
46a
14
24
23
20

FIG. 54

FIG. 55

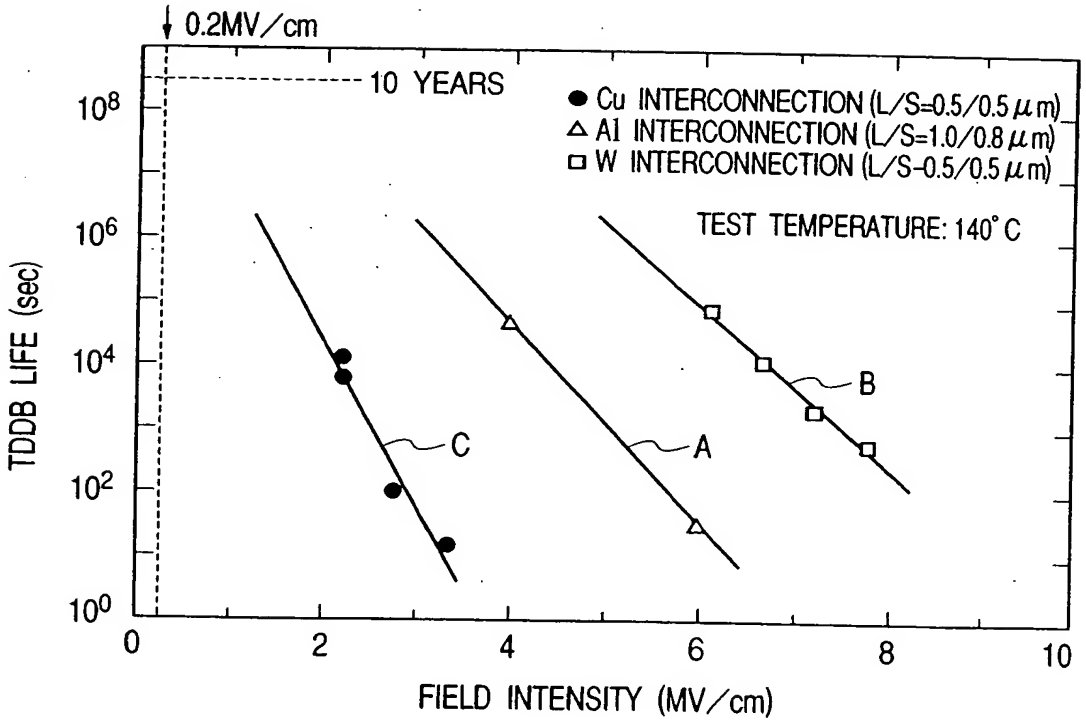

0.2MV/cm
10 YEARS
Cu INTERCONNECTION (L/S=0.5/0.5 μm)
Al INTERCONNECTION (L/S=1.0/0.8 μm)
W INTERCONNECTION (L/S-0.5/0.5 μm)
TEST TEMPERATURE: 140° C
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10
A
B
C
FIELD INTENSITY (MV/cm)

FIG. 56

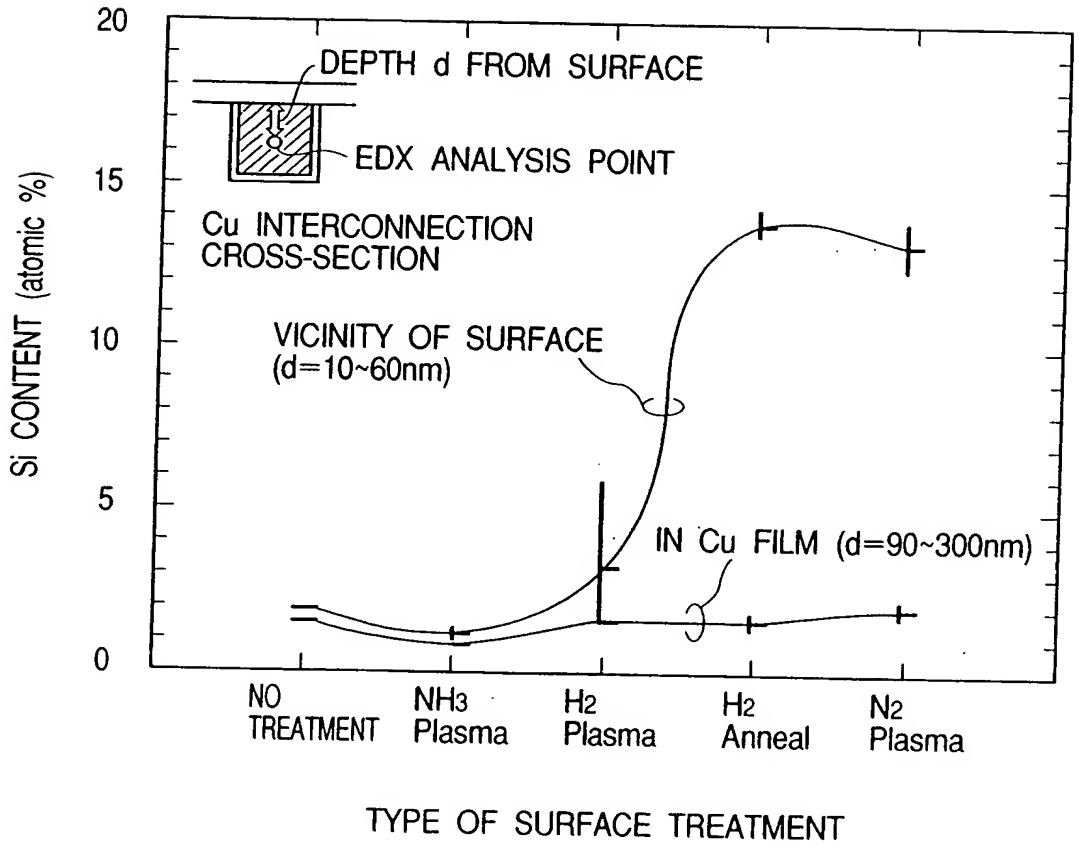
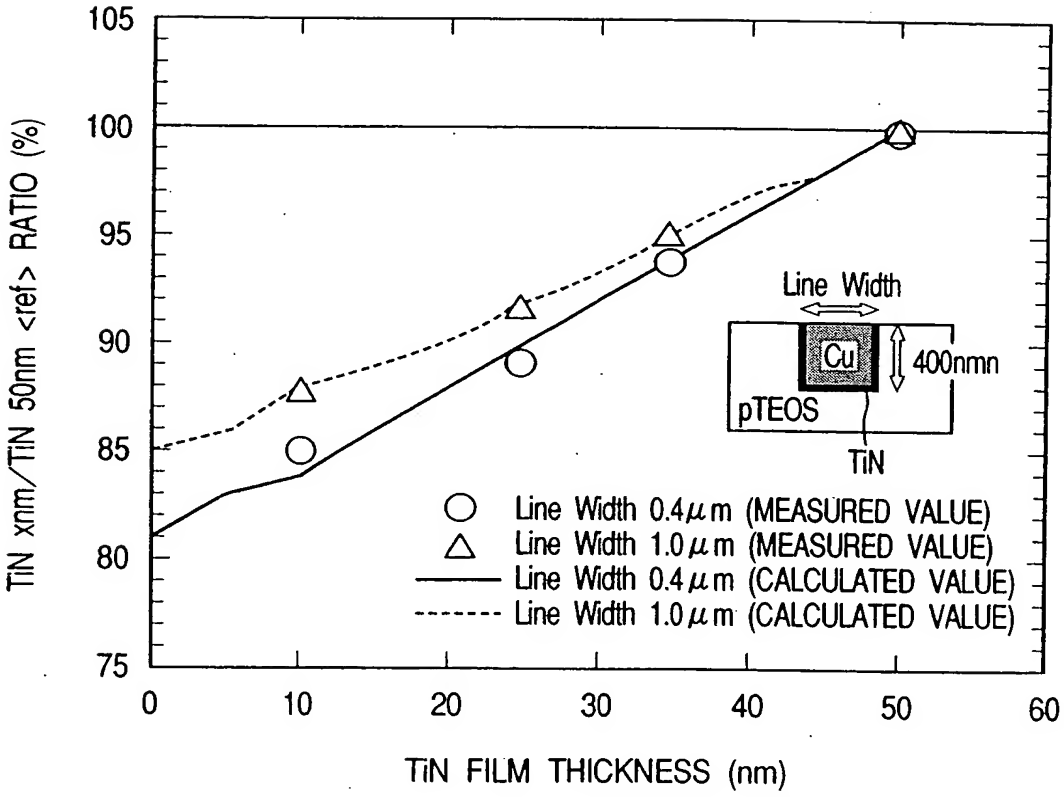

20
15
10
5
0
Si CONTENT (atomic %)
DEPTH d FROM SURFACE
EDX ANALYSIS POINT
Cu INTERCONNECTION
CROSS-SECTION
VICINITY OF SURFACE
(d=10~60nm)
IN Cu FILM (d=90~300nm)
NO TREATMENT
NH3 Plasma
H2 Plasma
H2 Anneal
N2 Plasma
TYPE OF SURFACE TREATMENT

FIG. 57



*TiN FILM THICKNESS=FILM THICKNESS AT BASE OF SLOT

FIG. 58

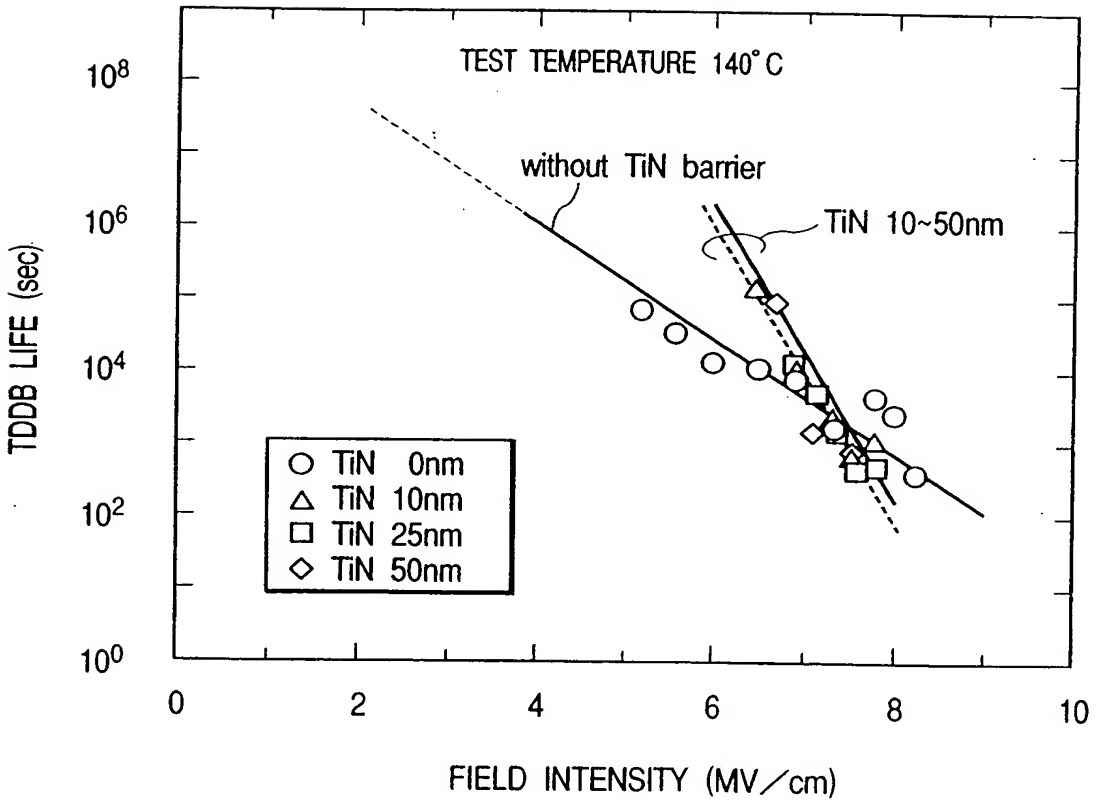

TEST TEMPERATURE 140°C
without TiN barrier
TiN 10~50nm
TiN 0nm
TiN 10nm
TiN 25nm
TiN 50nm
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10
FIELD INTENSITY (MV/cm)

FIG. 59

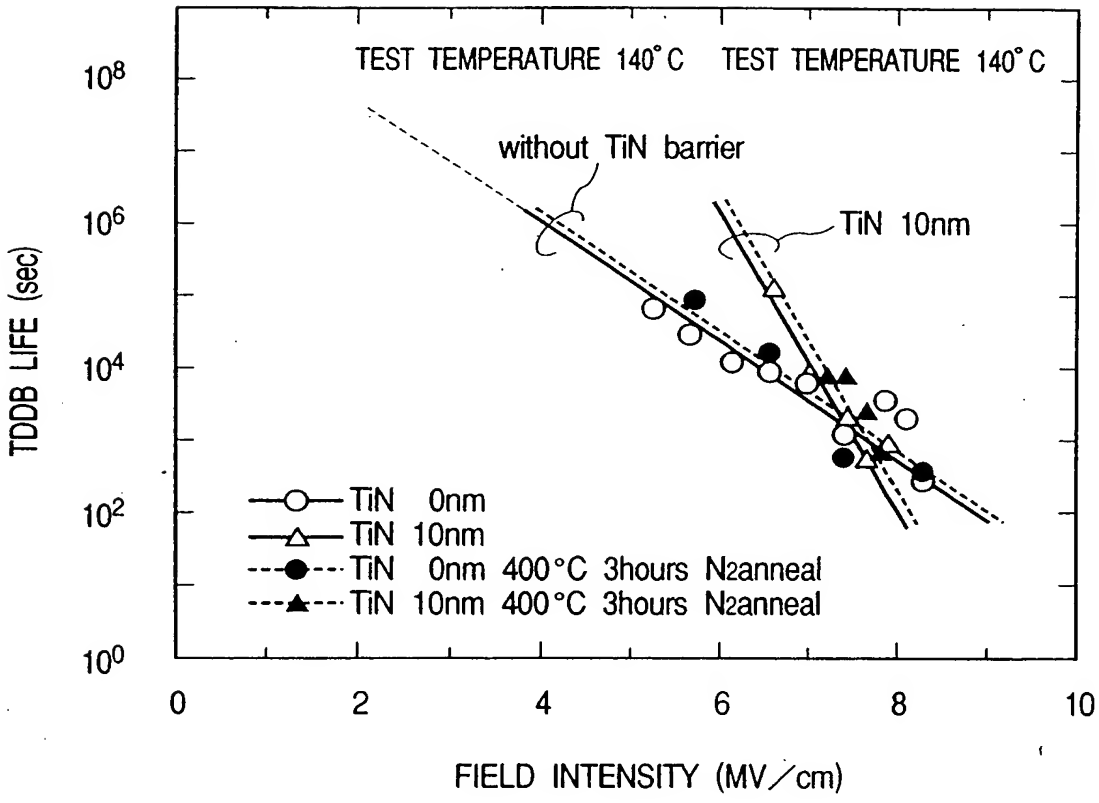

TEST TEMPERATURE 140°C
TEST TEMPERATURE 140°C
without TiN barrier
TiN 10nm
TiN 0nm
TiN 10nm
TiN 0nm 400°C 3hours N2anneal
TiN 10nm 400°C 3hours N2anneal
TDDB LIFE (sec)
10^8
10^6
10^4
10^2
10^0
0
2
4
6
8
10
FIELD INTENSITY (MV/cm)

FIG. 60(a)

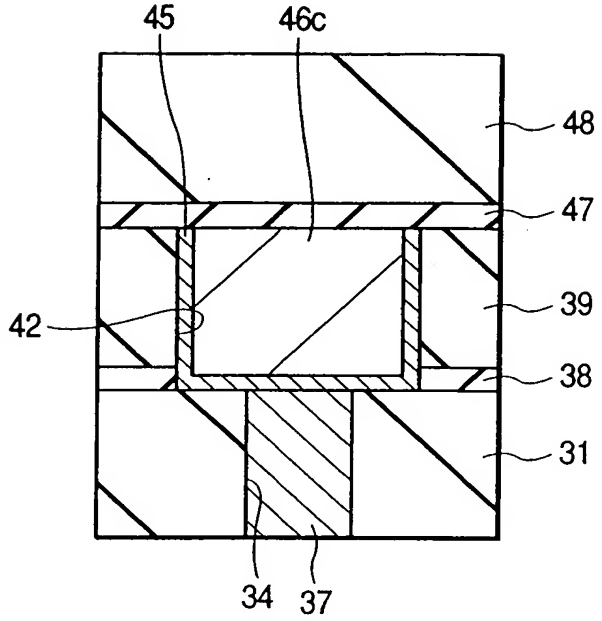


FIG. 60(b)

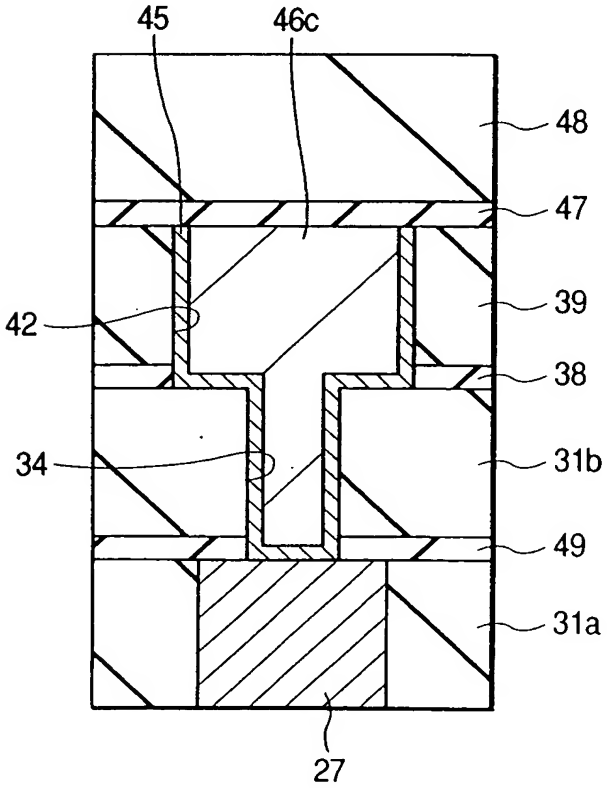


FIG. 61(a)

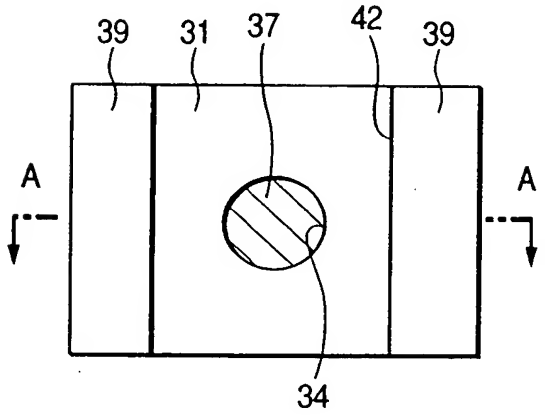


FIG. 61(b)

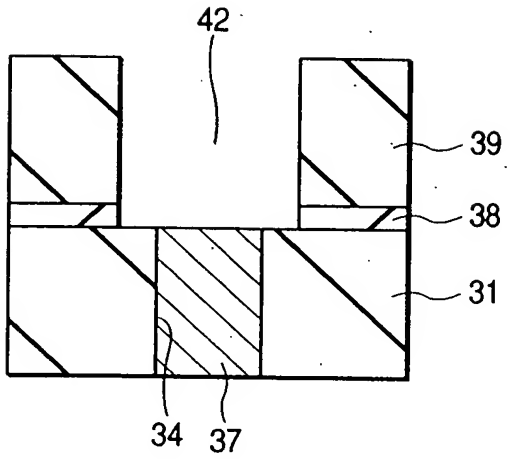


FIG. 62(a)

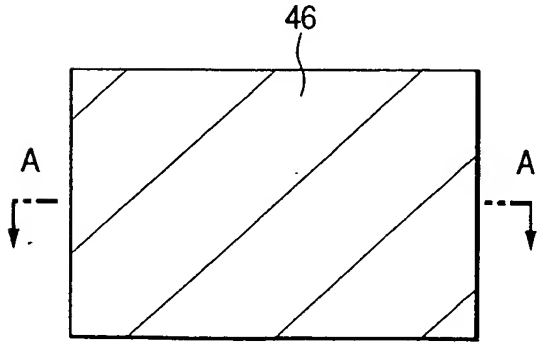


FIG. 62(b)

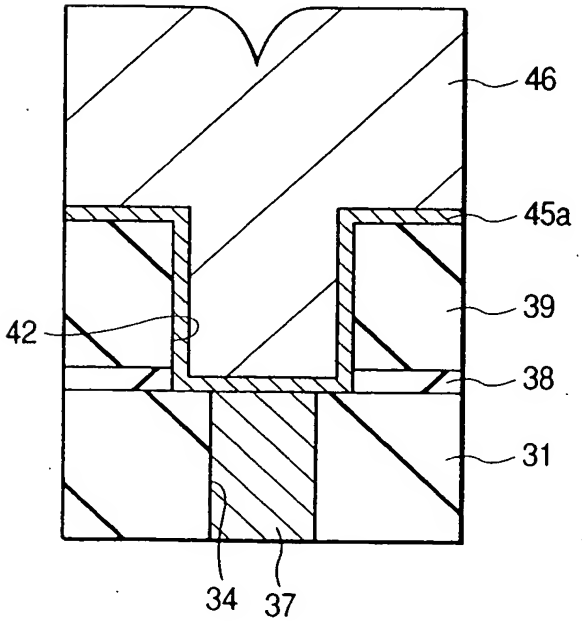


FIG. 63(a)

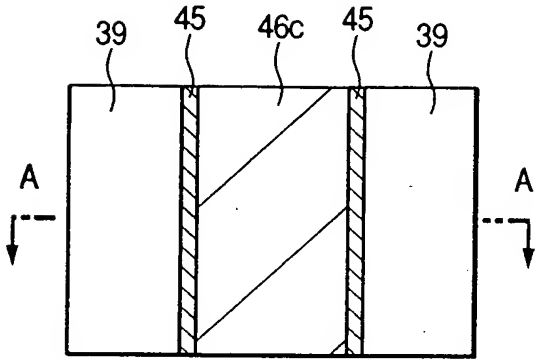


FIG. 63(b)

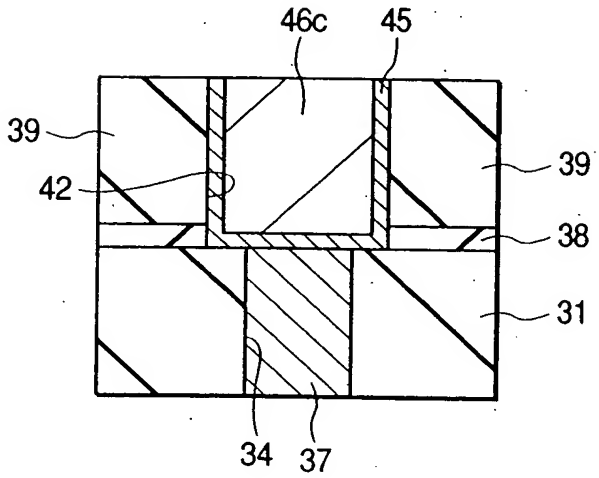


FIG. 64(a)

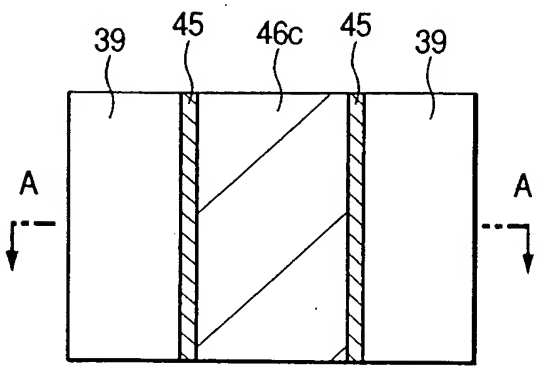


FIG. 64(b)

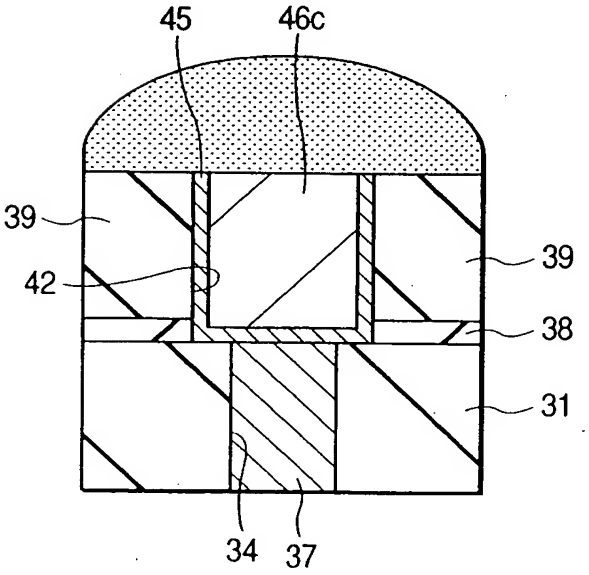


FIG. 65(a)

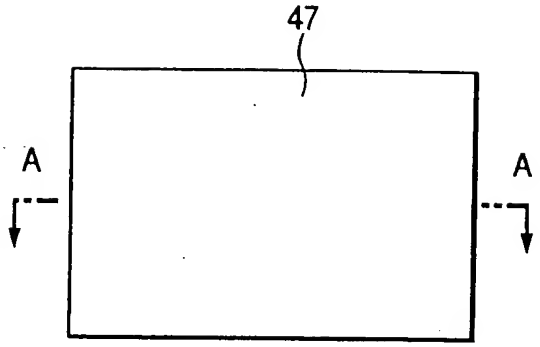


FIG. 65(b)

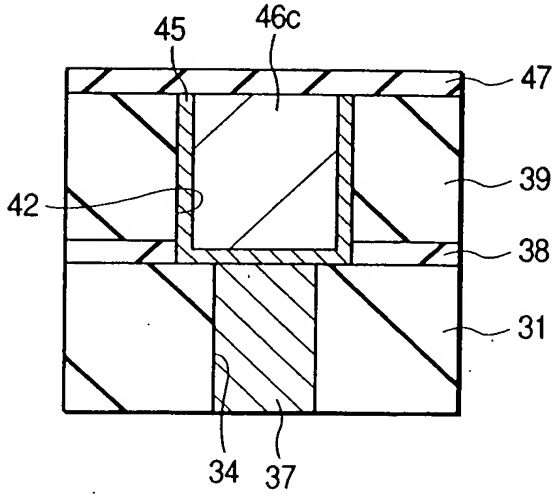


FIG. 66(a)

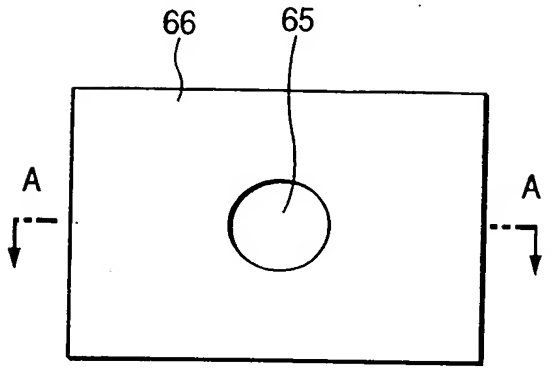


FIG. 66(b)

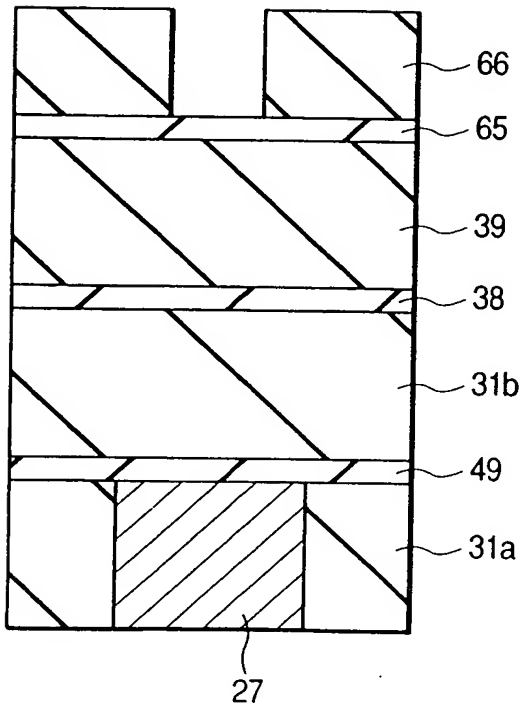


FIG. 67(a)

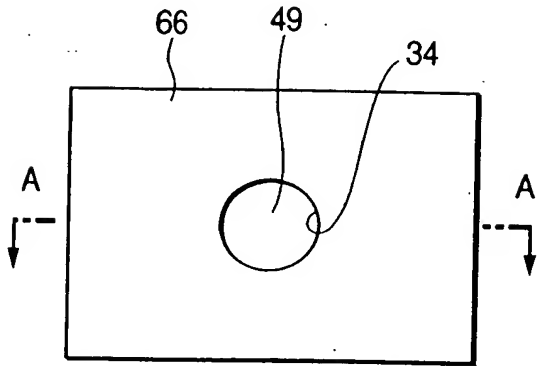


FIG. 67(b)

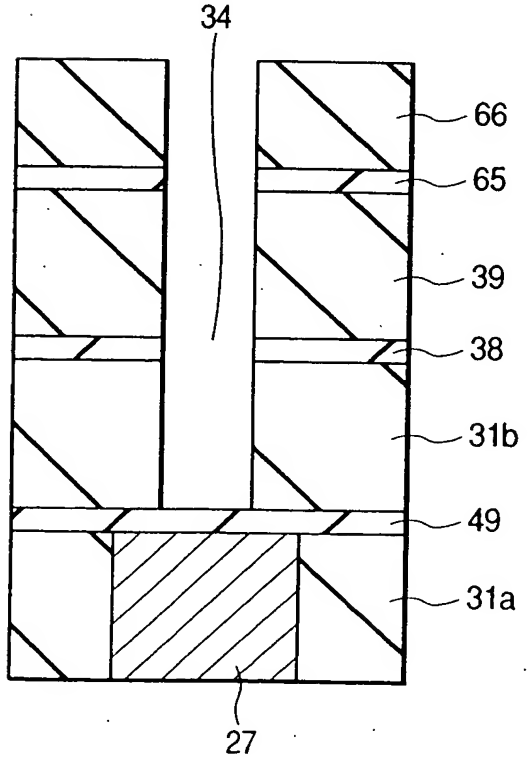


FIG. 68(a)

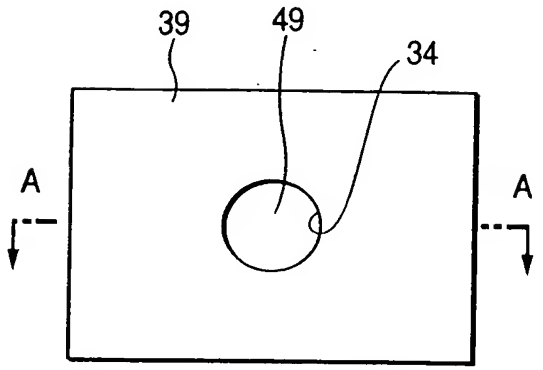


FIG. 68(b)

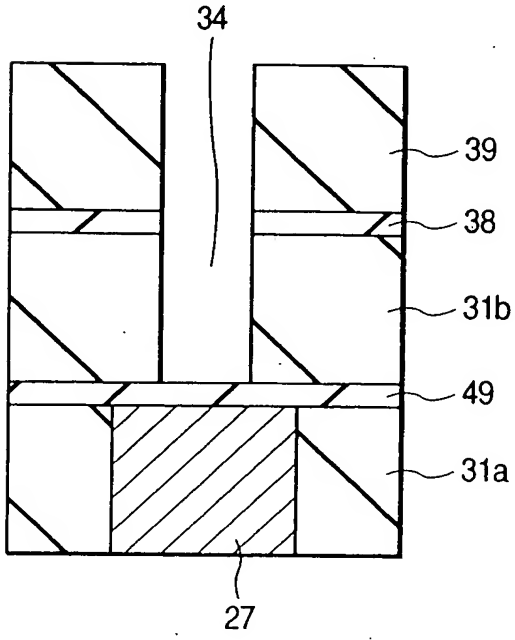


FIG. 69(a)

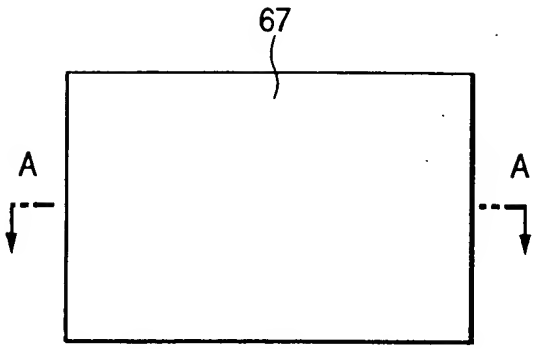


FIG. 69(b)

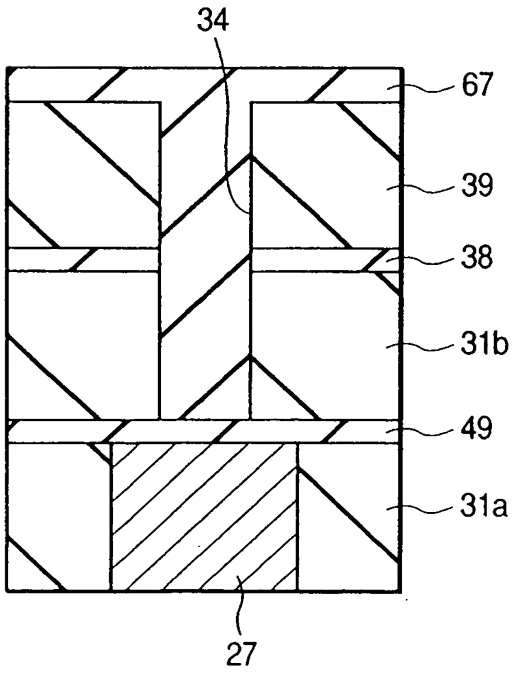


FIG. 70(a)

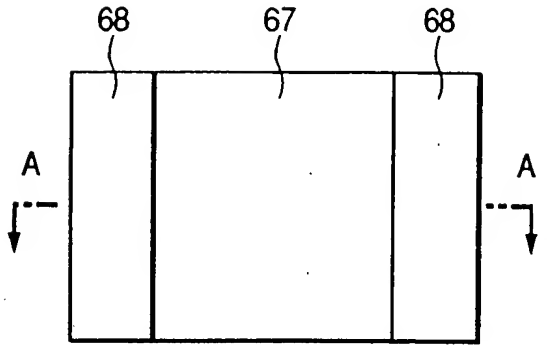


FIG. 70(b)

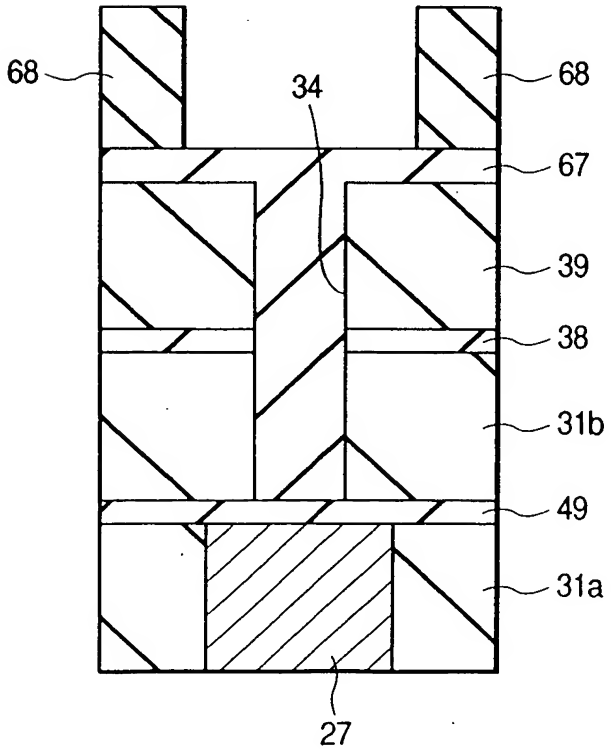


FIG. 71(a)

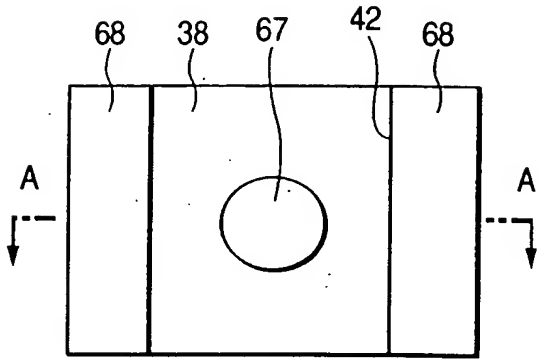


FIG. 71(b)

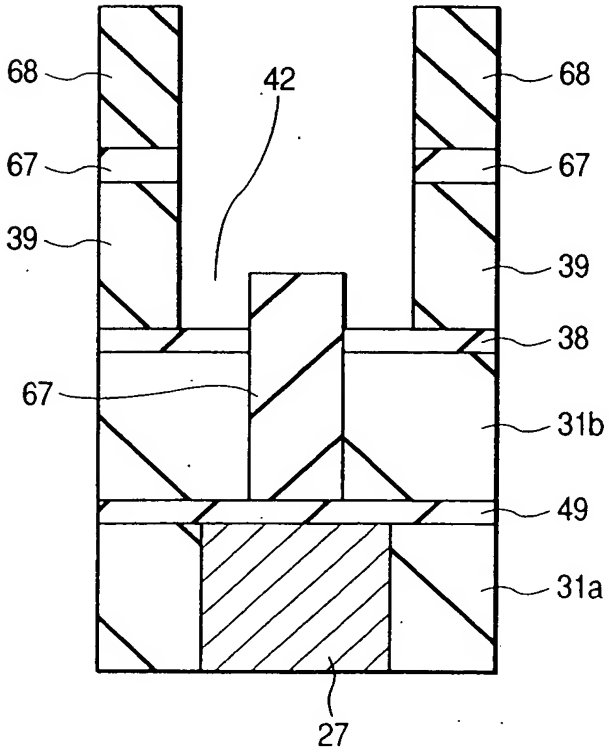


FIG. 72(a)

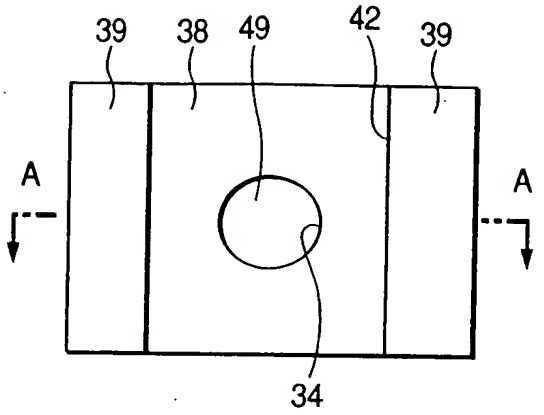


FIG. 72(b)

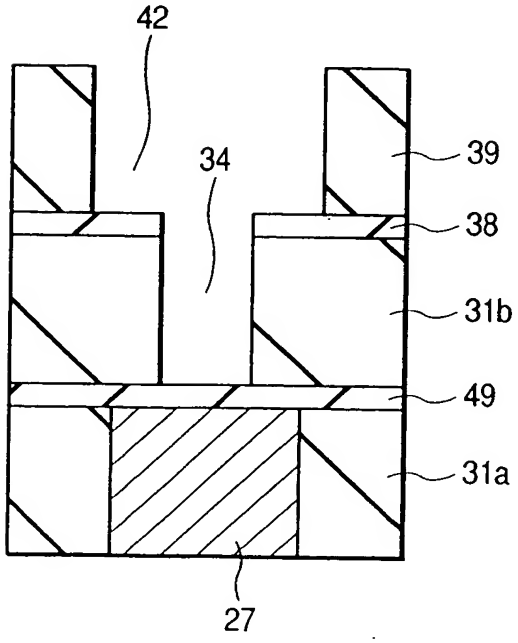


FIG. 73(a)

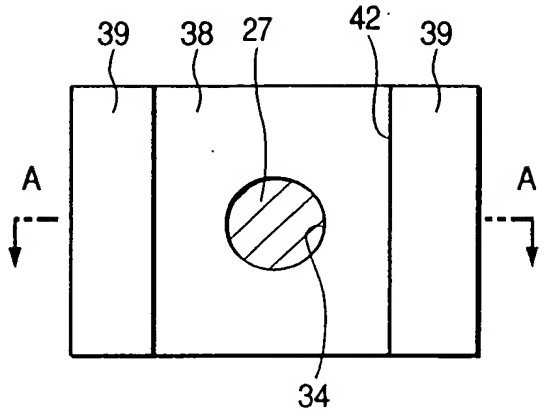


FIG. 73(b)

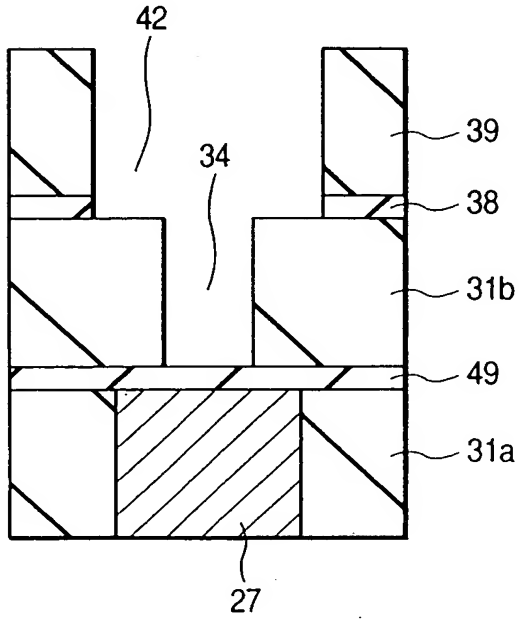


FIG. 74(a)

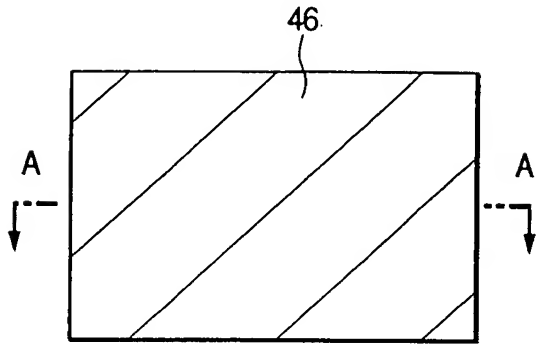


FIG. 74(b)

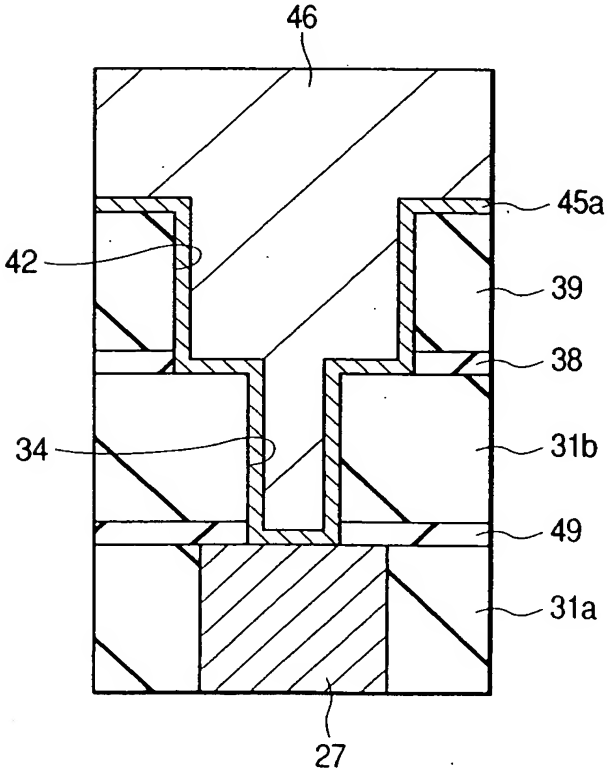


FIG. 75(a)

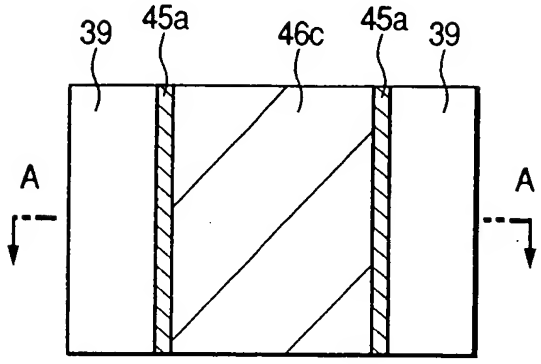


FIG. 75(b)

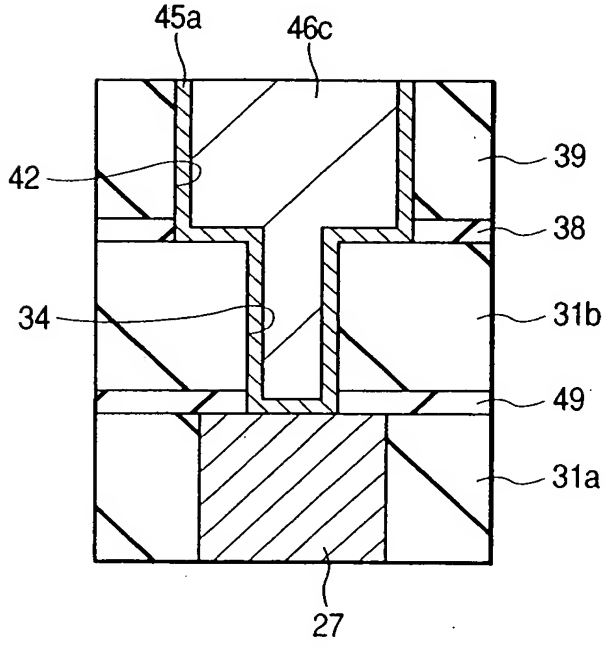


FIG. 76(a)

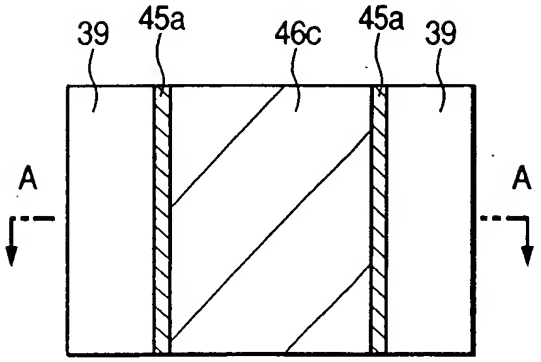


FIG. 76(b)

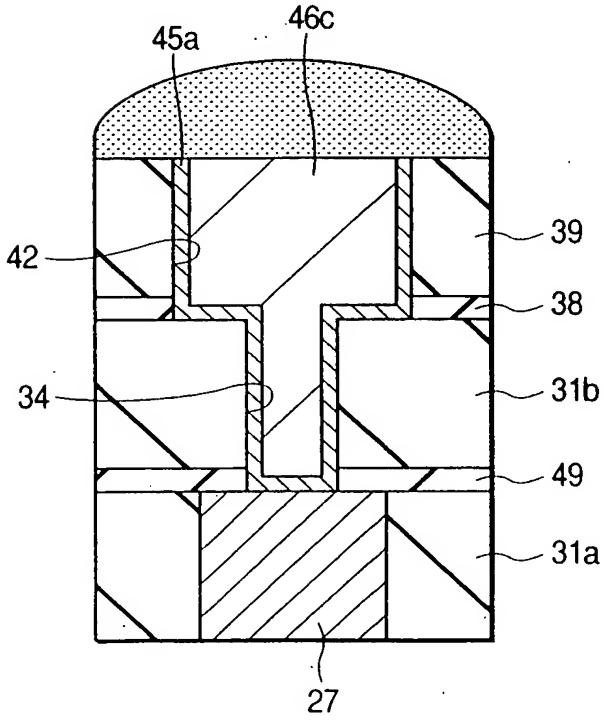


FIG. 77(a)

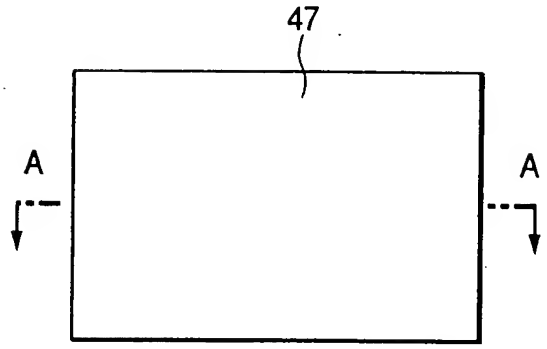


FIG. 77(b)

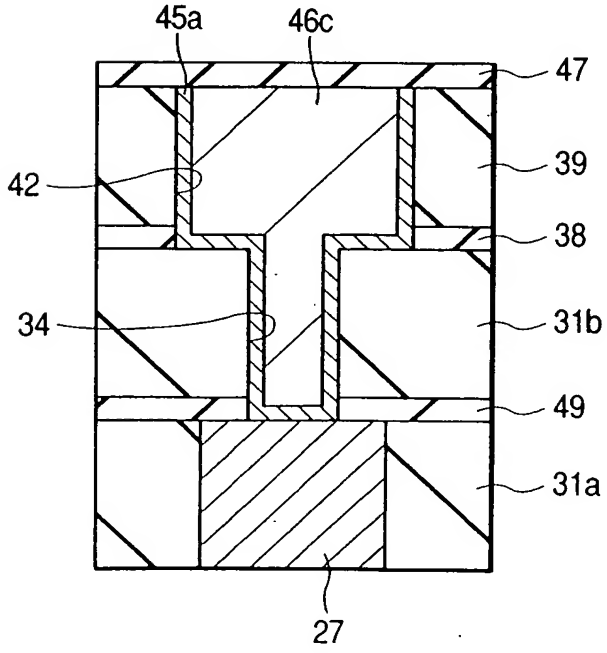


FIG. 78(a)

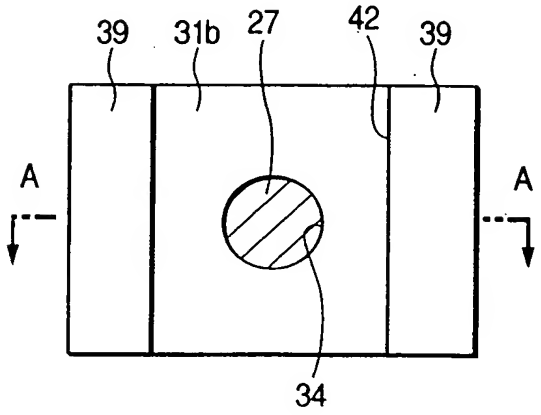


FIG. 78(b)

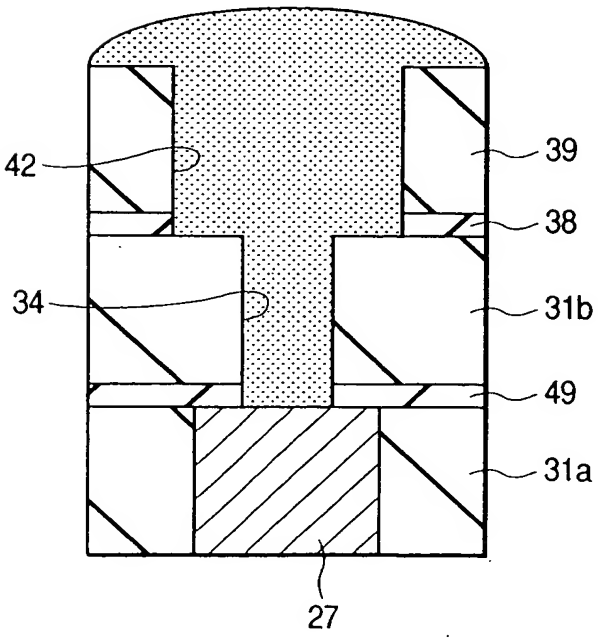


FIG. 79(a)

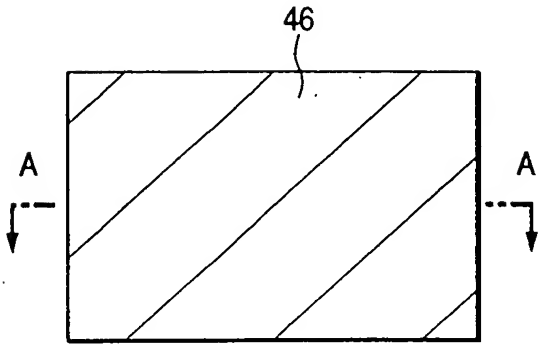


FIG. 79(b)

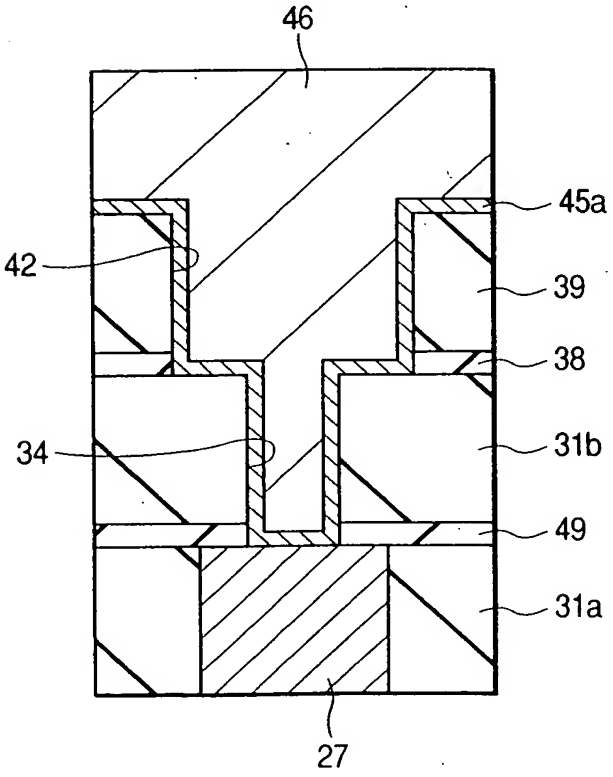


FIG. 80(a)

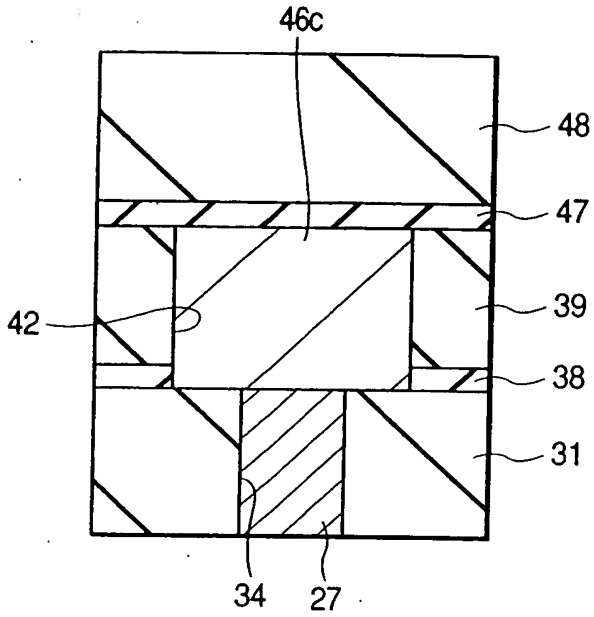


FIG. 80(b)

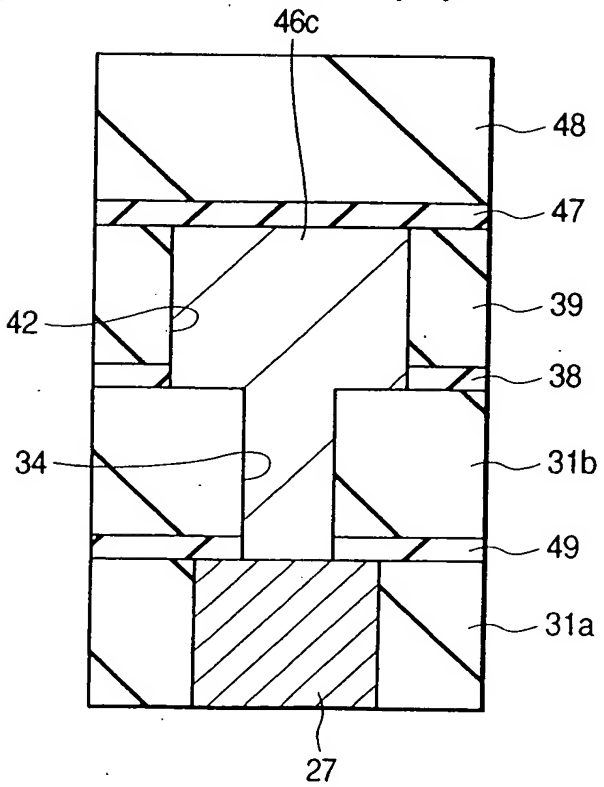


FIG. 81(a)

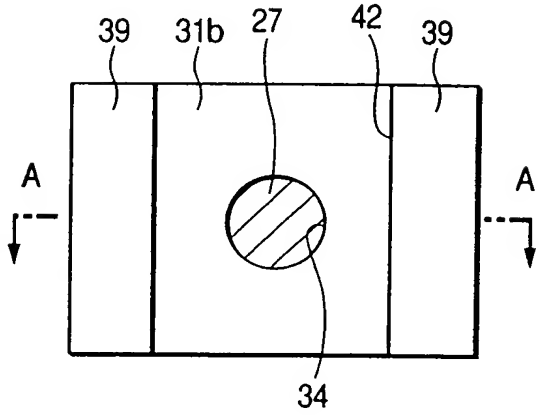


FIG. 81(b)

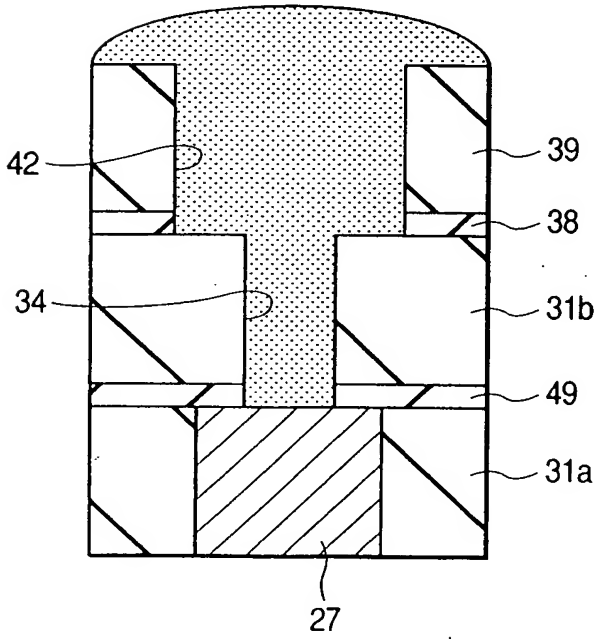


FIG. 82(a)

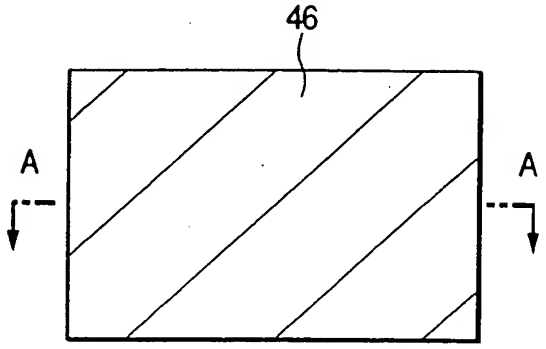


FIG. 82(b)

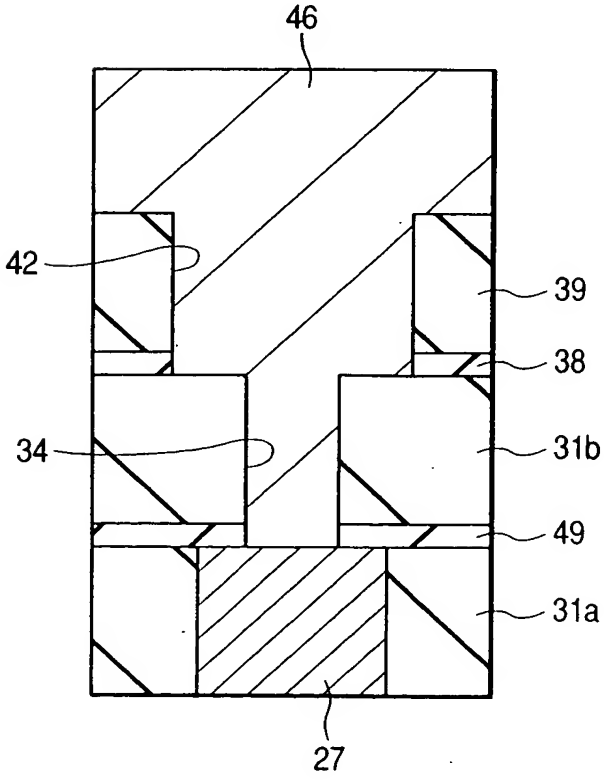


FIG. 83(a)

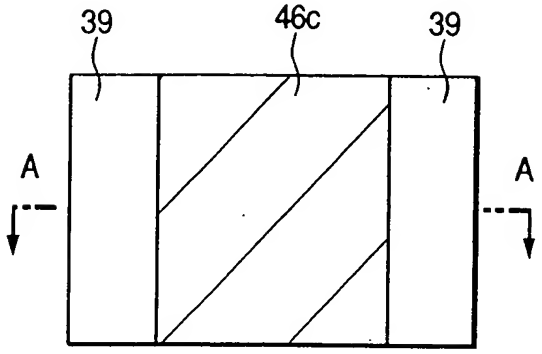


FIG. 83(b)

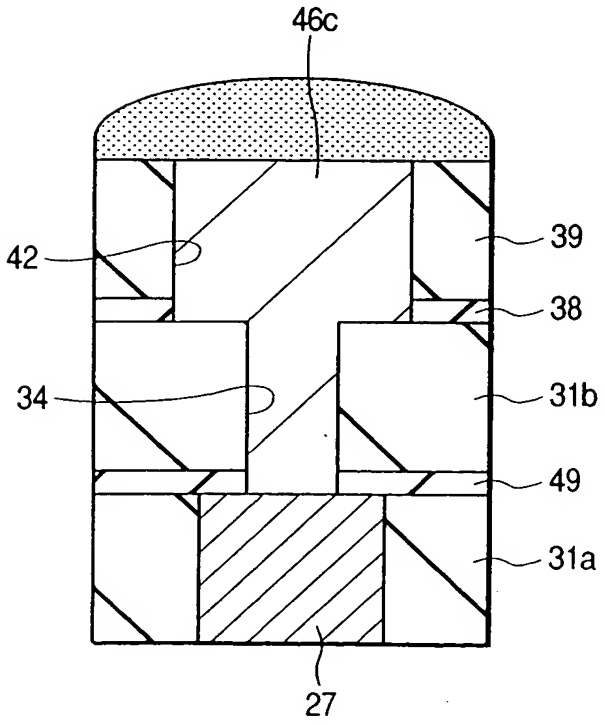


FIG. 84(a)

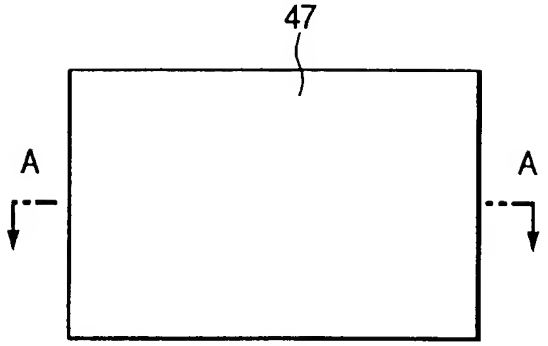


FIG. 84(b)

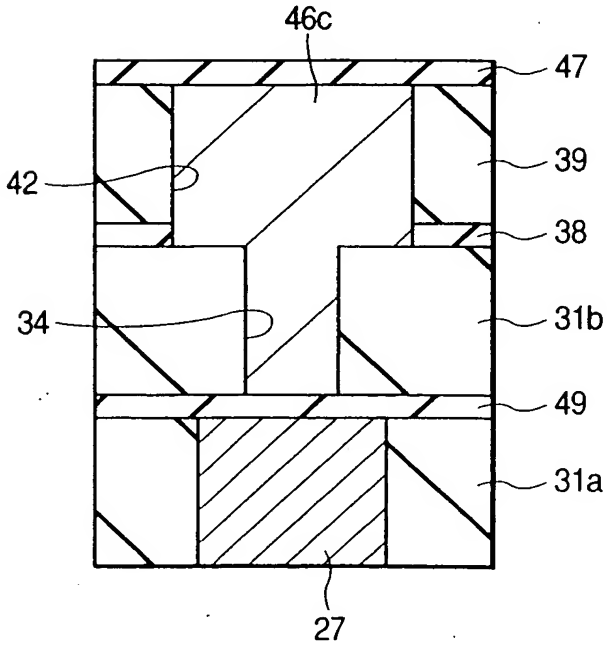


FIG. 85(a)

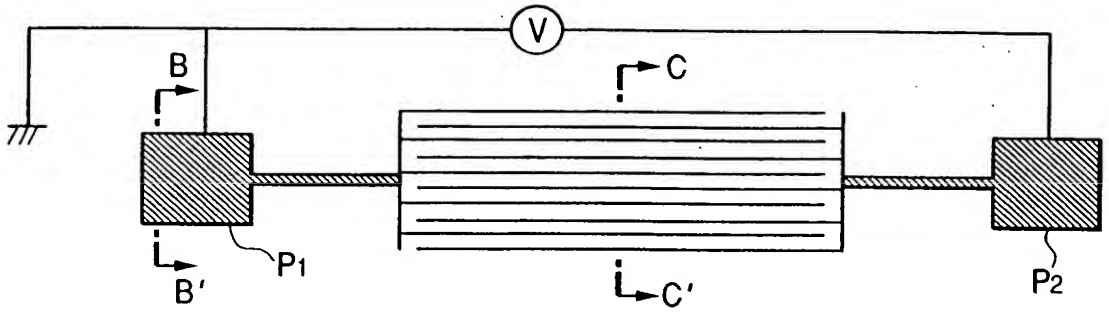


FIG. 85(b)

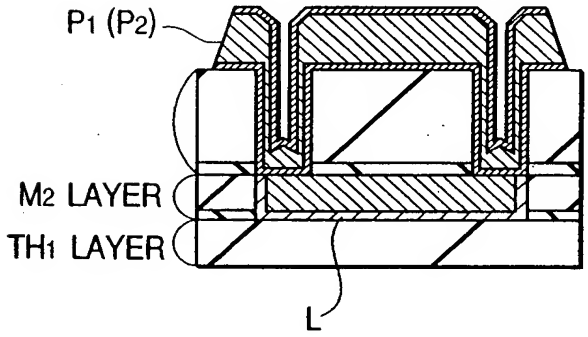


FIG. 85(c)

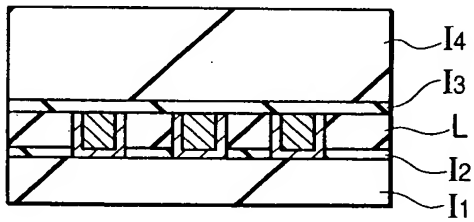


FIG. 86

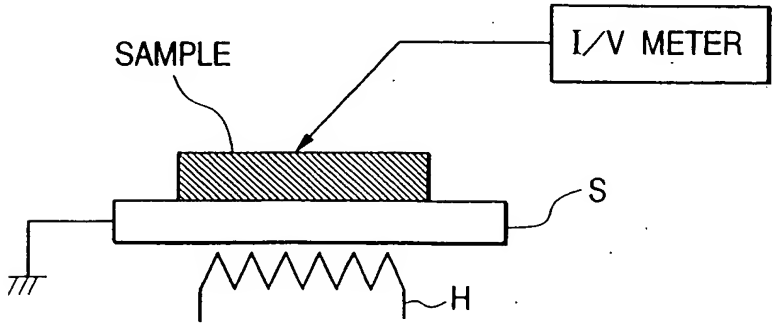


FIG. 87

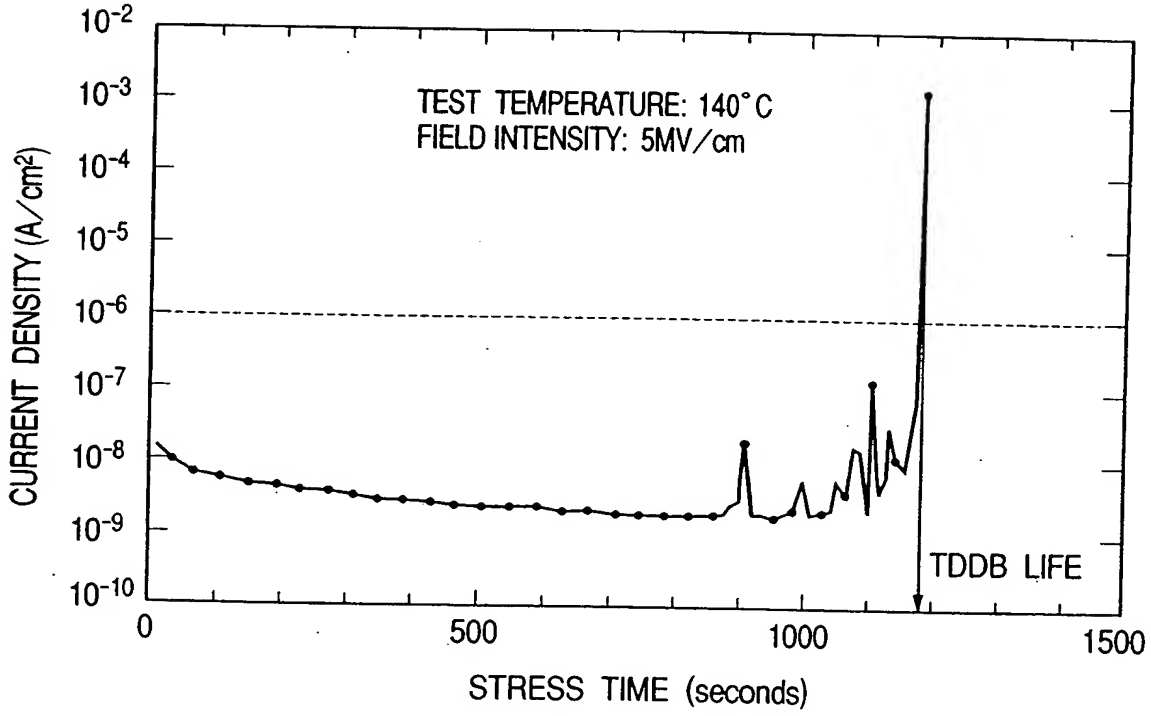

TEST TEMPERATURE: 140°C
FIELD INTENSITY: 5MV/cm
TDDB LIFE
CURRENT DENSITY (A/cm²)
STRESS TIME (seconds)
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
0
500
1000
1500

FIG. 88